File with N76-17079

NASA
#08 CR-137771

ATS-69607

WASHINGTON UNIVERSITY

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
DEPARTMENT OF CIVIL ENGINEERING

VOLUME II

DEVELOPMEMT OF AIR TRANSPORTATION

EVALUATION PROCESSES

NASA Contract NAS2-8324

August 28, 1975

Dr. Lonnie E. Haefner
Principal Investigator

VOLUME II

DEVELOPMENT OF AIR TRANSPORTATION EVALUATION PROCESSES

NASA Contract NAS2-8324

August 28, 1975

Department of Civil Engineering
Washington University
St. Louis, Missouri 63130

Dr. Lonnie E. Haefner
Principal Investigator

TABLE OF CONTENTS

Page

LIST OF FIGURES

FIGURE NO.	TITLE	Page
21	Typical Downtown STOL Port Layout	119
22	Peripheral STOL/VTOL Developer's Dilemma	135
23	Partial Bayesian Decision Tree for Peripheral Development	138
24	Case Study Potential Peripheral STOL/VTOL Location	143
25	Four Gate STOL Facility for Peripheral Location	148
26	Actor Group Interaction	174
27	Emerging Coalesced Groups in Case Study Peripheral Location Decisions Patterns	180
28	Alternative States of Metropolitan St. Louis Regional Development	186
29	Alternative 1	191
30	Alternative 2	192
31	Alternative 3	193
32	Alternative 4	194
33	Alternative 5	195
34	Alternative 6	196

LIST OF TABLES

TABLE NO.	TITLE	Page

CHAPTER I

INTRODUCTION

This volume is one of two volumes which comprise the final report and documentation of research results and associated computer software resulting from NASA Contract NAS2-8324, entitled, "Development of Air Transportation Evaluation Processes". The accompanying Volume I, State of the Art Review of Transportation Evaluation Techniques Relevant to Air Transportation, is a state of the art report and annotated bibliography of micro-economics, engineering economics and multi-dimensional system analytic processes of current relevance to complex ground transportation problems, ~~and~~ which have potential similar relevance to air transportation problems.[1] This Volume II is a compendium of case study and example problem tests of evaluation routines developed and synthesized for application to specific air transportation problems which have been chosen for further study of their decision patterns during the contract period. This introductory chapter will overview the research objectives of the study effort, the study design employed, and the potential benefits from the completed research, and orient the reader to the detailed case study and example problem compendium which forms the substance of Volume II.

Objectives of the Research

Modern air transportation takes many forms, and has a profound effect on the activities, land use and economic and social well being of our society. Any component form of air travel, and its interface with other transportation and public works systems forms a highly complex problem which requires systematic study and evaluation in order to assure the highest payoff to society per resources invested.

The above issues were addressed in the research activities documented herein and in Volume I. General evaluation formats for air transportation issues were developed which are typical of the current state of the art endeavors in multimodal transportation systems evaluation. The specific objectives of the research were:

1) Assess current multimodal transportation planning evaluation capabilities for their use in air transport problems.
2) Develop patterns of evaluation routines which are accurate and efficient for certain types of air transport problems.
3) Through (1) and (2) above, develop capabilities which assure all parties affected by air transportation decisions a role in the evaluation.
4) Develop, through incorporation of such evaluation formats, techniques for orderly program justification of agency research and capital investment strategies related to air transportation decisions.

Critical Aspects of Transportation Planning Evaluation Relevant to Air Transportation

Several aspects of multimodal transportation planning evaluation are relevant to air transport problems. They are:

1) Air transport alternatives, particularly supporting facilities, have varying degrees of flexibility. Further, the positive and negative impacts of employing such alternatives, are not known with certainty. Thus, we see a system of decision under uncertainty.

2) Decisions are often made which are hierarchial, and time sensitive. That is, they must fit within some larger policy scheme, and be implemented, part by part, over time to provide maximum benefits. Thus, the decision system is dynamic.

3) Evaluation responses to items relevant to the decision process will be broader than quantifying on the basis of purely monetary criteria. Thus, some calculus which allows subjective multi-dimensional weighting of all impacts is necessary.

4) To this end, specific participant groups concerned with air transportation are likely to have their own preferences and objectives, possibly different from those of other groups.

5) Potential exists for conflict in stating such preferences, and pressuring for alternatives to accommodate them in the decision process, can occur across all interested groups. Thus, the decision system can be one embodying conflict.

In the ensuing research, evaluation modelling patterns which run the gamut from very narrow and precise monetary evaluation techniques to very subjective and comprehensive citizen participation processes were investigated with respect to their capability of satisfying such critical aspects as noted above.

Benefits of the Research

The primary benefits of detailed evaluation modelling research in air transportation problems include:

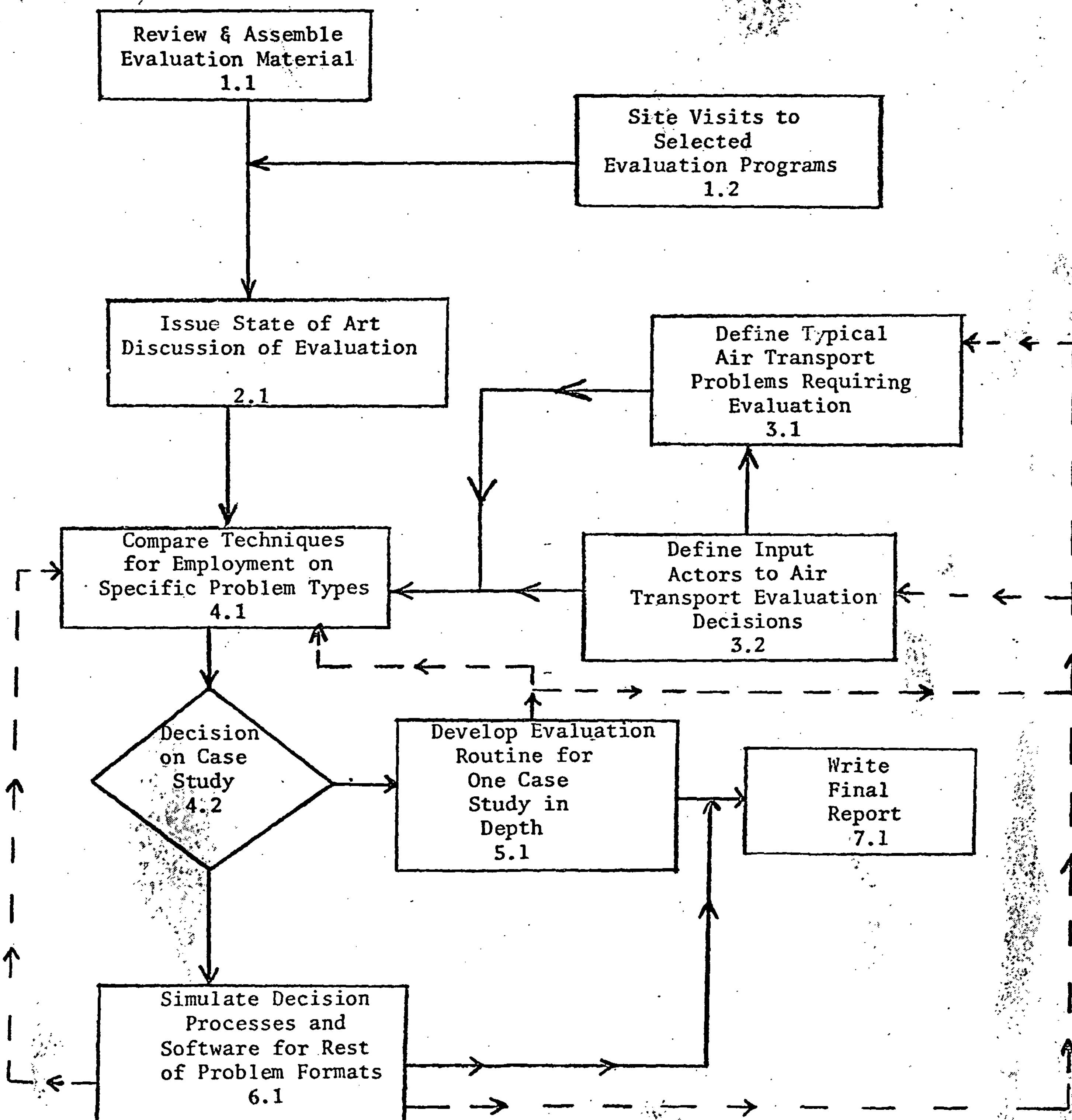
1) A deeper and more orderly understanding of processes which occur in making decisions relating to air transportation planning and investment alternatives.
2) A more comprehensive set of inputs to the above, developed through analytic mechanisms which allow all actors in the decision process to participate.
3) Rationale for justification and defense of research, development, demonstration and capital investment programs.
4) A more integrated view of the relationship of research findings to planning and capital investment in air transportation activities.

Research Work Plan

The accompanying Figure 1 shows the flow of work during the study period. It consisted of seven major phases, some with component tasks.

Figure 1

Work Plan



Phase 1

Phase 1 consisted of two tasks. The first task, 1.1, reviewed and assembled appropriate literature and case studies on all ranges of multimodal transportation evaluation. Task 1.2 made selected phone contacts and visits to sites where innovative and comprehensive multidisciplinary evaluation programs have been undertaken, such as the Boston Transportation Planning Review, the Prince Georges County I-95 study in Baltimore, and the emerging BART study. Due to the specialization and interests of the Principal Investigator, almost all of task 1.1 was underway at the time of initiation of the study. Previous project visits and intensive classroom use of the reports on the Boston Transportation Planning Review and the Prince Georges I-95 study allowed the Site Visits to be reduced to an in-depth review of the BART Program with their Executive Director and their Impact Study Staff. Complete discussion of the status of the BART Impact Program and other innovative citizen participation evaluation study programs can be found in Volume I.[2]

Phase 2

Phase 2 had one task, that of aggregating and analyzing the material from Phase 1 and issuing a state of art discussion of evaluation techniques. This discussion is completely documented as Volume I of this research activity, and contains a broad spectrum of techniques which are relevant.[3] The reader is encouraged to review Volume I for a complete overview of available evaluation approaches.

Phase 3

Phase 3 consisted of two tasks. Task 3.1 concentrated on the definition of typical air transport problems and issues requiring orderly evaluation techniques. The following problems were considered:

A) Intercity Long Haul Passenger Transport

B) Air Freight Systems

C) Technology Development

D) Air Commuter Systems - STOL, VTOL

E) Interface of Air Transportation into Regional and Metropolitan Multimodal Transportation Planning Decisions - and Airport Location Decisions.

Task 3.2 catelogued actors, participants and those having vested interests in the above problems, including:

Governmental Agencies and Jurisdictions

Affected Citizens

Air Travelers

Air Shippers

Carriers

Airport Facility Operators

Industrial and Technological Components

Affected Regions, Subregions and Local Communities.

Both tasks 3.1 and 3.2 initially developed lists which were not exhaustive, and were subsequently refined and modified through discussion with the Contract Monitor and continuing review of airline annual reports and airport engineering literature. In both tasks 3.1 and 3.2, the study team attempted to accurately understand the decision processes and the

critical issues as they unfold in the real world, and the input of the pertinent actors, as a prelude to developing categorization of impacts and their problems, case study selection, and ultimate evaluation approaches in phases 4 through 6.

Phase 4

Phase 4 consisted of two tasks. The first, Task 4.1, through appropriate study of the evaluation capabilities from Phase 2, and the problem structures, from Phase 3, attempted to make some preliminary statements about evaluation structures which could be employed on each of the problem types to yield an orderly, more algorithmic approach to specific problem evaluation. This phase was looked upon as a critical matching of real world problem and analytic effort in order to yield a stronger problem structure and allow it to be operational in a logical, solution producing manner.

Task 4.2 used the information generated thus far to choose one typical problem for further in depth case study, while delineating other typical problems to be dealt with at a laboratory level of simulation of typical decisions. The decision on choice of case study was made jointly through discussion with the client, considering current metropolitan, regional and national problems at hand, availability of data, cooperation of participants, and critical issues demanding immediate solution. The final mutual choice of the study team and the NASA project officer was a case study of the location and public works planning evaluation and

implementation processes of STOL and VTOL facilities in a regional land use and transportation plan.

Phase 5

Phase 5 employed several promising evaluation approaches on the above case study problem, using a metropolitan region in the Midwestern United States as the scenario enviornment, and employing real world transportation, land use, demographic and cost data for the region. Appropriate software documentation of the evaluation approaches was developed,and Chapter V of this volume is a complete coverage of the case study research activity.

Phase 6

Phase 6 dealt with some specific residual problem types not chosen for case study. Here, in Task 6.1, a series of "typical situations" were developed, and evaluation and decision processes simulated, using the potentially appropriate evaluation techniques matched in Phase 4. Computer software routines to operationalize these for actual problem use were also completed. The example problems and their analyses are the topics of Chapters II,III and IV. The problems developed and evaluated in a synthetic manner include:

- Fare and route Request Analyses
- Rural Commuter Airline Scheduling for remote locations and sparse demand.

Selection algorithms for Programing Air Transportation Technology Research and Development Programs

Phase 7 of the research was the synthesis of the above example problems and case study into this final report volume. The reader is referred to Chapters II, III and IV of this document for intensive discussion of the analysis of the above example problems. Chapter V deals with the comprehensive STOL/VTOL case study, and Chapter 6 offers appropriate conclusions and discussion of future research needs.

Two critical points must be made in concluding the preliminary overview of Phases 5,6 and 7:

1) No illusions should exist about "clean modelling" or a perfect abstraction of any of the problems into an existing algorithm. Certain patterns of real world decision problems can be captured to varying extents by various evaluation structures. Data and criteria gaps will exist. Thus, the matching of approaches and problems in Phase 4 becomes one of adapting and synthesizing evaluation tools to adequately capture the problem.
2) To this end, several techniques, each attempted individually, or often attempted by being merged as hybrids were necessary to adequately capture the problem structures. Thus, iteration of Phases 5 and 6 occured throughout the research program, to employ the cut and try process of selection of evaluation routines. In situations where two approaches appeared to give adequate

answers to a common problem, attempts were made to compare the routines on basis of cost, efficiency, data or other relevant criteria. These iterative processes occured as feedbacks shown in the work-plan of Figure 1, to phases of problem definition, catelogues of participants, and matching of analytic approaches.

FOOTNOTES

Haefner, L.E. Principal Investigator,

1) A State-of-the-Art Review of Transportation Systems Evaluation Techniques Relevant to Air Transportation; Project Report, Volume I for NASA Contract NAS2-8324, Washington University, St. Louis, MO, August 28, 1975.

2) Ibid., pp. 100-108.

3) Haefner, Loc. Cit.

CHAPTER II

EXAMPLE PROBLEMS

AIRLINE FARE, ROUTE AND DEMAND ALLOCATION ANALYSIS

The example problems covered in this chapter deal with the use of analytic techniques in domestic airline operations analysis and strategy formulation. Two related problems are examined in this chapter. The first is an analysis of fare level changes using statistical decision theory in conjunction with a conventional fare model. The second problem is the study of route requests using utility theory.

Problem 1 - Analysis Strategies for Fare Level Changes

The objective of this technique is to provide management with a preliminary analysis tool which yields initial conclusions as to strategies to pursue with respect to rate alterations. Its strengths are that it is simple, and does not require a highly detailed market analysis, but rather utilizes relevant past history of CAB responses to rate changes, and aggregate predictors of growth in air travel needs. The problem approach will be demonstrated by initially discussing a

conventional fare model, and then utilizing it in a statistical decision theory approach to yield preliminary rate strategy results.

The following model was developed to determine fares for a specified, after tax, discounted cash-flow return on investment.[1] The model uses 12 years for the depreciation period.

$$\text{Fare}=\left(\frac{A}{lf} \cdot \frac{T_B}{U} \cdot \frac{IC}{N}\right) + \frac{TOC}{LF \times N}$$

where:

A= constant dependent on the rate of return and depreciation period

lf= load factor, the ratio of passengers to available seats

T_B= flight block time in hours

U = aircraft annual utilization (hours per year)

IC= total initial cost of the air craft, $ per unit (1.3 times the individual aircraft cost to account for equipment and spares.)

N = number of available seats per aircraft

TOC= total operating cost = DOC + IOC = $ per flight

DOC= direct operating cost

IOC= indirect operating cost

A= .1503 and .0948 for 12% and 8% ROI, respectively

The above gives a simple estimate for the appropriate fare on a route.

The following four routes were chosen for testing the model in this research: St. Louis-Chicago, St. Louis-Dallas, St. Louis-Denver, and St. Louis to Los Angeles. All of these routes have Boeing 727 aircraft flown on them daily, and as such allow for reasonably equitable comparison of costs and fares. Cost information was taken from 1972, and rate information was taken from March 1, 1975.[2]

All rates used are one way, coach. The cost data was projected to current 1975, using an inflation rate of 1.08 per year. The 1975 calculated fare compared against the 1975 actual fare charged appears in Table 1, with the percent difference between the two also shown. The model of calculated fare operated quite close to fares actually charged, with the exception of the overstatement of the appropriate calculated fare level against that actually charged for the short distance flight of St.Louis-Chicago. This may be due to the fact that the model does not include input concerning competition, or other market factors which affect travel demand, and ultimately fares for trips of this relatively short distance. Table 2 shows typical inputs for computation of fares for several aircraft types for the St. Louis-Dallas route.

TABLE 1

ACTUAL VERSUS CALCULATED FARES USING CONVENTIONAL FARE MODEL

Route	Actual Coach Fare March 1, 1975	Boeing 727 Aircraft	
		1975 Calculated Fare using 1.08% inflation factor on costs	Percent Difference from Actual Fare
St. Louis-Chicago	$32.00	$36.28	13%
St. Louis-Dallas	$58.00	$56.89	-2%
St. Louis-Denver	$75.00	$71.23	-5%
St. Louis-Los Angeles	$132.00	$124.93	-5%

TABLE 2

CONVENTIONAL FARE MODEL COMPUTATIONAL INPUTS

Type Aircraft	Fly Away Cost	IC (millions of dollars)	N	1972 TOC_d	1975 TOC_d
747	24m	31.2	374	6157.3	7756.41
DC-10	17m	22.1	270	4515.77	5688.56
L-1011	17m	22.1	270	4515.77	5688.56
707	9.8m	12.74	125	3756.37	4731.94
DC-8	12.6m	16.38	140	4369.60	5504.44
727-200	7.5m	9.75	134	3004.47	3784.76
727-100	6.1m	7.93	94	2733.33	3443.20

A = 12% = .1503

8% = .0948

lf= .55

U = 3000 hrs per year

d = 545 miles St. Louis-Dallas

T_b = 1.41 hours

TABLE 3

DEMAND LEVELS AND ASSOCIATED PROBABILITIES

Dallas to St. Louis Route

Current Fare = $58.00 Current Annual Demand = 345,000 passengers

Yearly Forecast Demand State S_i x 1 = 1, ----, 4	P (S_i)	Demand Range (Annual Passengers)
1	.1	≤ 340,000
2	.4	340,001 to 360,000
3	.3	360,001 to 375,000
4	.2	> 375,000

The necessity for a simple preliminary analytic tool for isolating fare strategies can be linked with the above conventional fare model to yield some feel for demand, competitive and regulatory issues. Assume that a current fare has been developed by the conventional model illustrated above, and further, that some general airline passenger forecasting capabilities exist, yielding price-elasticity insights into potential demand at various calculated fare levels. An airline desires to preliminarily map a strategy for rate change, without further in-depth costly attitudinal or marketing study endeavors. If the present aggregate demand and price-elastic forecasting relationships are such that information shown in Table 3 can be synthesized with respect to subjective feel for probabilities of the different demand states, the strategy can be mapped using statistical decision theory, jointly employing subjective and probabilistic assessments of past CAB reactions to rate changes.

The problem is formulated in a decision tree format as shown in Figure 2. The rate requests are viewed as a set of experiments, whose only outcomes are their being approved or disapproved. If approved, the new rate goes into effect and impacts travel demand in a manner consistent with price-elastic relationships discernable with the present forecasting tools. If the rate is disapproved, the current base rate of $58.00 is kept, and the price demand levels and probabilities of Table 3 are presumed to apply. Further, past history of CAB responses to rate changes of various increments can be used to subjectively

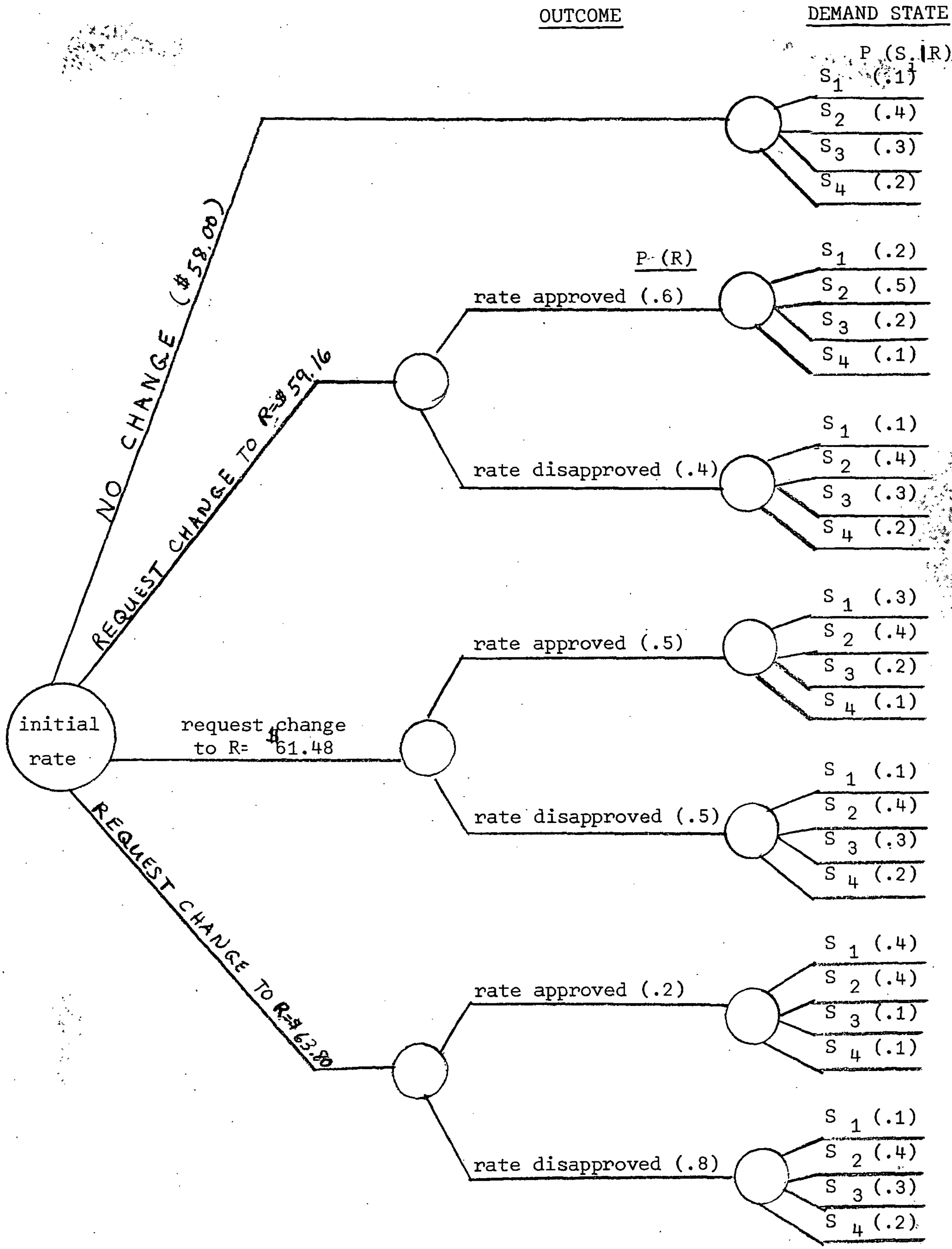


Figure 2

DECISION TREE FORMAT

Table 4

ANALYSIS INPUTS

R= Fare Request	Probability of Rate being Approved P(R)	Demand State S_i	$P(S_i \mid R)$
$59.16	.6	1	.2
		2	.5
		3	.2
		4	.1
$61.48	.5	1	.3
		2	.4
		3	.2
		4	.1
$63.80	.2	1	.4
		2	.4
		3	.1
		4	.1

forecast a probability of approval of each particular rate level under consideration. This information is synthesized in Table 4, which illustrates the potential rate requests, the possible future states of demand S_i, corresponding to those in Table 3, the $P(S_i|R)$, (the probability of such a demand state given the associated rate level, determined from the aggregate demand and price-elasticity forecasting tools) and $P(R)$, which is the probability of CAB approval of such a rate level, given the past history and subjective analysis of CAB response. Likewise, these elements are portrayed graphically in Figure 2.

Thus, computation proceeds down the decision tree according to the following formula:

$$E_R = \left[\sum_{i=1}^{4} S_i P(S_i|R)\right] P(R) + \left[\sum_{i=1}^{4} S_i \, P(S_i|R)\right] P(R')$$

and $E^* = \underset{R}{\text{Max}}\ E_R$

where:

E_R = Expected Revenue Associated with Rate Request to Rate R

E^* = Maximum Expected Reserve, Associated with Optimal Strategy of Rate Request.

S_i, $P(S_i | R)$ and $P(R)$ as defined previously with respect to Table 4.

$P(S_i | R')$ = The probability demand state i occuring given the rate request was dissapproved, i.e., the present demand response at base rate of $58.00 as shown in Table 3 is presumed to continue.

$P(R') = 1 - P(R)$ = The probability of disapproval of rate request R.

To appropriately estimate the expected revenues, some demand figure within each demand state must be employed in the computations which the analyst feels appropriate. To articulate this problem, the representative levels in Table 5 were chosen, with state 1 represented 5,000 below its bound, and state 4 at 5,000 above its lower bound, and states 2 and 3 at the midpoint of their range. The results of the analysis are shown in Table 6. Given the probabilities of rate change acceptance, and price demand relationships of Table IV, it is apparent that the optimal strategy is to pursue a rate request of $61.48. Only a marginal increase in revenue can be gained by the request of $59.16, and expected revenue is relatively less at the rate request of $63.80, due to the low probability of CAB approval. Thus, the maximizing hedge on revenues exists at a rate level of $61.48.

Table 5

REPRESENTATIVE DEMAND LEVELS FOR COMPUTATION

S_i	Demand Level for Computational Purposes
1	335,000
2	350,000
3	367,500
4	380,000

Table 6

EXPECTED REVENUE COMPUTATIONAL RESULTS

R	E_R
\$58.00 (present fare)	\$20,865,500
\$59.16	\$20,894,036
\$61.48 = E^*	\$21,253,230
\$63.80	\$21,142,450

Conclusions - Commentary on Approach

Several summary comments are relevant on the technique used in the above example:

1) It is simple and inexpensive to process.

2) As previously stated, its purpose is as a preliminary delineation of strategy, allowing use of current forecasting information, and requiring at this level, no further detailed marketing analysis. It allows preliminary analysis of dominance or break-even points from pursuit of particular rate strategies.

3) Although it works almost totally with subjective and probabilistic information, and demand bounds and levels supplied by the decision maker, it utilizes his experience and historical "feel" for the above entities in the problem environment in a logical and orderly manner. Thus he is able to view the decision tree problem as a comprehensive format, yet simultaneously perceive the individual magnitudes of sensitivity to rate approval or demand shifts that the ultimate strategy to be pursued hinges on. As such, a complete sensitivity analysis over several rate levels, component demand shifts, and approval-disapproval response can be performed in an efficient and informational manner.

Problem 2 - Use of Utility Theory in Route Analysis

The second problem reviews the use of utility theory in developing an airline's perspective as to strategy of which of several possible routes it should apply for in expanding its services.

To fly an additional route or to serve new points requires a certificate of public convenience and necessity from the CAB. The CAB reviews the following questions in route cases:

a) will the new service serve a useful public purpose, responsive to a public need,

b) whether this service can and will be served adequately by existing routes or carriers,

c) whether it can be served by the applicant without imparing the operations of existing carriers contrary to the public interest.

d) whether any cost of the proposed service to the Government will be outweighed by the benefit which will accrue to the public from the new service.

e) whether the applicant is "fit, willing, and able to perform such transportation properly".[3]

With all the above aspects which the Board must analyze, the possibility for conflict between airlines is very high. An applicant may be applying for a new service, or the establishment of a service

competitive with another airline. Sometimes there are many applicants for the right to operate over a given route. Because of the limited traffic on that route, it may be impossible to allow more than one carrier authorization. By granting of a certificate to a particular applicant, the public may be penalized, while granting it to another airline might be advantageous to the public in the form of better service. There is also the problem of building a strong industry and the possible conflicts of large and small airlines. Should the strong get larger or should the weaker and possibly more inefficient airlines be encouraged to expand? In addition, the CAB is under obligation to protect the existing carriers from new operations and the dilution of revenues. The overall profit level of a carrier at its present operating level, as well as any potential loss to a new competitor, is an important factor in the final decision.

In considering route applications the CAB decides each case by weighting the variables particular to that specific case. The particular circumstances in each route case are never identical, and the issue of competition, *per se*, is not a mandatory criteria for determining any particular route allocation.[4]

The establishment of routes for trunk lines follows the formal procedure illustrated in Figure 3. The procedure begins with an airline making a request to the CAB for a route award between cities A and B. The CAB route committee then sets a deadline for additional

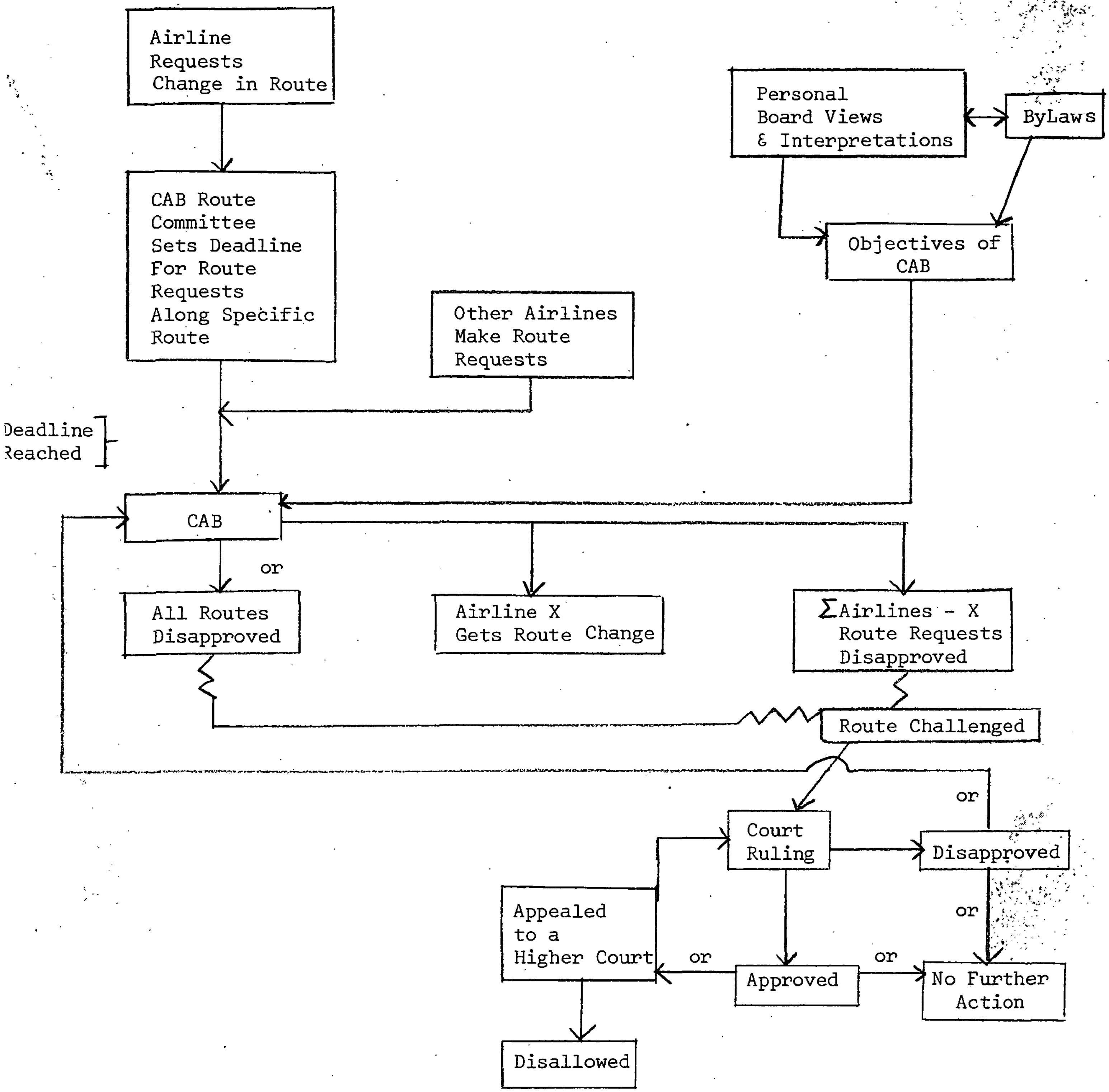


Figure 3

Route Request Allocation Proceedings

route requests between cities A and B. During this period of time, other airlines also file their requests for the route between cities A and B. At the appropriate deadline, the CAB reviews the briefs submitted by the carriers and may also request outside groups who might be affected to appear before the Board. In the decision reached, either all of the route requests may be denied, or one carrier may be awarded the route, thus denying awards to all other carriers who also filed. The unsuccessful carriers do have recourse through the courts to attempt having the decision stayed and the hearings reopened.

The analysis of the addition of a route which is acceptable in terms of the carrier's objectives is of extreme importance in sound airline management. The general pattern of the decision structure can be developed through use of some aspects of utility theory. Initially, general factors of market competitiveness, market durability, and productive ability of the carrier are identified as relevant to the decision. Components of the above factors are detailed and ranked from very good to very poor, with a numerical ranking ranging from 2 for very poor to 10 for very good. Tables 7, 8 and 9 review levels of these components and their ratings.

The airline must review the relative importance of the above factor components in light of their objectives, and the characteristics

of their present size, market, equipment inventory, financial position and personnel pool. A relative weighting of each of these component factors of Tables 7, 8 and 9 on a scale of 100, reflecting their importance to the firm is shown in Table 10.

The analysis can be effected as shown in Table 11. We define:

$$U = \text{Expected utility of a route} = \sum_{i=1}^{8} U_i$$

$$\text{and } U_i = \left[\sum_j (P_{ij} L_j) \right] W_j$$

where i = 1, - - ,8 component factors listed in Table 10

j = 1, - - - -,5 levels of quality of these factors, such levels articulated in Tables 7, 8 and 9.

L_j = score associated with level j as follows:

L_1 = Very good = 10

.
.
.
.
.

L_5 = Very poor = 2

P_{ij} = the probability of factor i being at a particular level j.

$$\sum_j P_{ij} = 1.00$$

These probabilities form the stochastic elements shown in Table 11.

Table 7

MARKETABILITY FACTORS AND LEVELS

FACTOR	LEVELS AND RATING				
	VERY GOOD = 10	GOOD = 8	AVERAGE = 6	POOR = 4	VERY POOR = 2
Effect on Sales on Other Routes	Will significantly aid sales on other routes	Possible small positive effect on other routes	No sales effect on other routes	Possible small negative effect on other routes	Will significantly hurt sales on other routes
Competitive Quality Differential	Can differentiate our airline favorably to others	Viewed above most of competitors on route	Viewed same as competitors	Viewed below a few of competitors on route	Viewed unfavorably to other carriers on route
Capability of Integration of Route into Airline's Current Route Structure	Can be ideally integrated into airline's route structure	Fits well into airline's route structure	Can be fitted into airline's route network	Causes problems by integrating into airline's network	Extreme difficulty in integration and servicing with composition of current route pattern

Table 8

DURABILITY FACTORS AND LEVELS

FACTOR	LEVEL AND RATING				
	VERY GOOD 10	GOOD 8	AVERAGE 6	POOR 4	VERY POOR 2
Size of market and number of competitors servicing the route	Large market and a moderate number of carriers servicing it	Large market and a few carriers servicing it	Medium market and a few carriers servicing it	Medium market and many carriers servicing it	Small market and many carriers servicing it
Resistance to economic fluctuations	Sales stable in inflation or depression	Moderately affected by economic cycles	Sales follow economic trends	Heavy dependence on economic conditions	Total dependence on economic conditions

Table 9

PRODUCTIVE ABILITY FACTORS AND LEVELS

FACTORS	LEVEL AND RATING				
	VERY GOOD 10	GOOD 8	AVERAGE 6	POOR 4	VERY POOR 2
Equipment necessary	Utilizes excess equipment	Utilizes present equipment	Some additional equipment necessary	Mostly new equipment required	All new equipment required
Personnel necessary	Utilizes present personnel exclusively	Marginal increase in new personnel required	Substantial increase in new personnel required	Large increase in new personnel required	Total new personnel group required
Facilities necessary	Facilities in existence, small capital and acquisition cost	Facilities in existence, some renovations cost required	Facilities in existence, extensive restoration cost	Some New facilities needed, extensive capital and acquisition costs	Totally new facilities needed, extremely large capital and acquisition costs

Table 10

FACTOR WEIGHTING TABLE RELATED TO FIRMS OBJECTIVES

	FACTOR	WEIGHT
1.	Effect on sales on other routes	7
2.	Competitive quality differential	12
3.	Capability of integration of route into airline's current route structure	17
4.	Resistance to economic fluctuations	10
5.	Size of market and number of competitors servicing route	18
6.	Equipment necessary	15
7.	Personnel necessary	12
8.	Facilities necessary	9
	TOTAL	100

The above probabilities are, as in the previous section, arrived at through historical knowledge and subjective experience with respect to aspects of competitiveness, market durability and equipment inventory performance of the airline. Previous cost, marketing and equipment life studies and models may also be considered valid input at arriving at the probabilities shown in Table 11. The analysis proceeds by developing the $\sum_j (P_{ij} L_j)$ shown numerically in column A in Table 11, and multiplying by W_i, to yield the specific U_i in column B. In the example shown, $U = \sum_i U_i = 678.3$, which is the expected utility to the airline in developing this particular route's service. Similar analysis can be performed with respect to other routes, against appropriate factor weightings with respect to objectives, and forecasting of levels of factor performance. Thus, a comparative analysis of resultant utilities associated with several route application options open to the airline can easily be made.

Concluding Commentary

As in the previous problem, the above has relevant advantages and limitations as an analysis tool:

1) It is simple and inexpensive to process, and easy to understand.

Table 11

EXPECTED UTILITY ANALYSIS

FACTOR i	FACTOR WEIGHT W_i	LEVEL J					COLUMN A	COLUMN B
		J=1 VERY GOOD (10)	J=2 GOOD (8)	J=3 AVERAGE (6)	J=4 POOR (4)	J=5 VERY POOR (2)	$J\ P_{i5}L_J$	U_i = contribution to total expected utility
1	7	.0	.2	.8	0	0	6.4	44.8
2	12	.0	.3	.6	.1	.0	6.4	76.8
3	17	.2	.6	.2	0	0	8	136
4	10	.0	.1	.7	.2	0	5.8	58
5	18	0	.1	.6	.3	.1	5.8	104.4
6	15	.4	.6	0	0	0	8.4	132
7	12	.2	.4	.4	0	0	5.8	69.6
8	9	.1	.5	.3	.1	0	6.3	56.7

$\Sigma = 100$

$\Sigma = U = 678.3$ for this route

It can be directly related to the firm's objectives in light of their own commercial strengths and weaknesses.

2) It allows different weightings on levels and factors to be tested for the capability of causing change in the ultimate strategy to be pursued. Thus, strength and accuracy of several points of view can be tested.

3) The analysis can incorporate any level of sophistication in formulating weights, scores and probabilities, from uninformed hunches to output of complex forecasting and analytical tools.

FOOTNOTES

1 Richard S. Shevell and David W. Jones, "Studies in Short Haul Air Transportation in the California Corridor," Volume I and II, NASA CR 114634 and Sudaar No. 460, Stanford University, Dept. of Aeronautics and Astronautics, July 1973.

2 Official Airline Guide; North America Edition, March 1, 1975, Volume I, No. 11, Reuben H. Donnelley Publication, 2000 Clearwater Drive, Oak Brook, Illinois 60521

3 Civil Aeronautics Act, (Sec. 401 (d))

4 Frederick, John Hutchinson, Commercial Air Transportation, 4th ed., Homewood, Illinois, R.D. Irwin, 1955, pg. 126.

CHAPTER III

EXAMPLE PROBLEM - RESEARCH AND DEVELOPMENT PROJECT EVALUATION IN AIR TRANSPORTATION

Introduction

The example problem in this chapter deals with a comprehensive analysis technique for evaluation of research and development project activity over a horizon period in air transportation. The techniques employed attempt to capture the dynamics and uncertainty of Research and Development endeavors, and deal with such in light of the objectives of an agency such as NASA, and relevant national concerns throughout the horizon period.

The construction,management and evaluation of sound short and long range plans for research and development have been historical problems in federal agencies such as NASA. The development of a theoretically sound, yet functional means to evaluate and optimize research and development (R & D) expenditures in the short run (typically 5 years) and in the long run (typically 20 years) is necessary to optimize society's use of money in the R & D process. Further, any technique to deal

with such a problem should be able to function within a typical agency management system such as a Planning, Programming, Budgeting System (PPBS). Any set of management and choice techniques should allow the agency decision-makers to integrate maximum use of subjective knowledge into the evaluation process. The following paragraphs delineate an approach for dealing with the R & D evaluation problem which employs Bayesian Decision Theory and Dynamic Programming within the PPBS structure. The discussion will initially deal with components of PPBS, then subsequently articulate the Bayesian Decision component, and ultimately integrate the problem in a format using Dynamic Programming.

Structural Entities of the Problem

The recent use of PPBS has consisted of two major structural components. The first of these is the goal-objectives structure, in which broad goals are articulated with a set of well-defined objectives underlying them which are relevant to an agency's operation. The second component of the PPBS structure is the hierarchical structure for planning and organizing agency expenditures. This structure consists of defined Program Areas, Program Groups, and Program Elements as shown in a reduced version in Figure 4. Theoretically, the hierarchy of Areas, Groups, and Elements relate directly to the achievement of one or more objectives in the Goal-Objectives structure.

The technique developed herein will deal with bundles of program

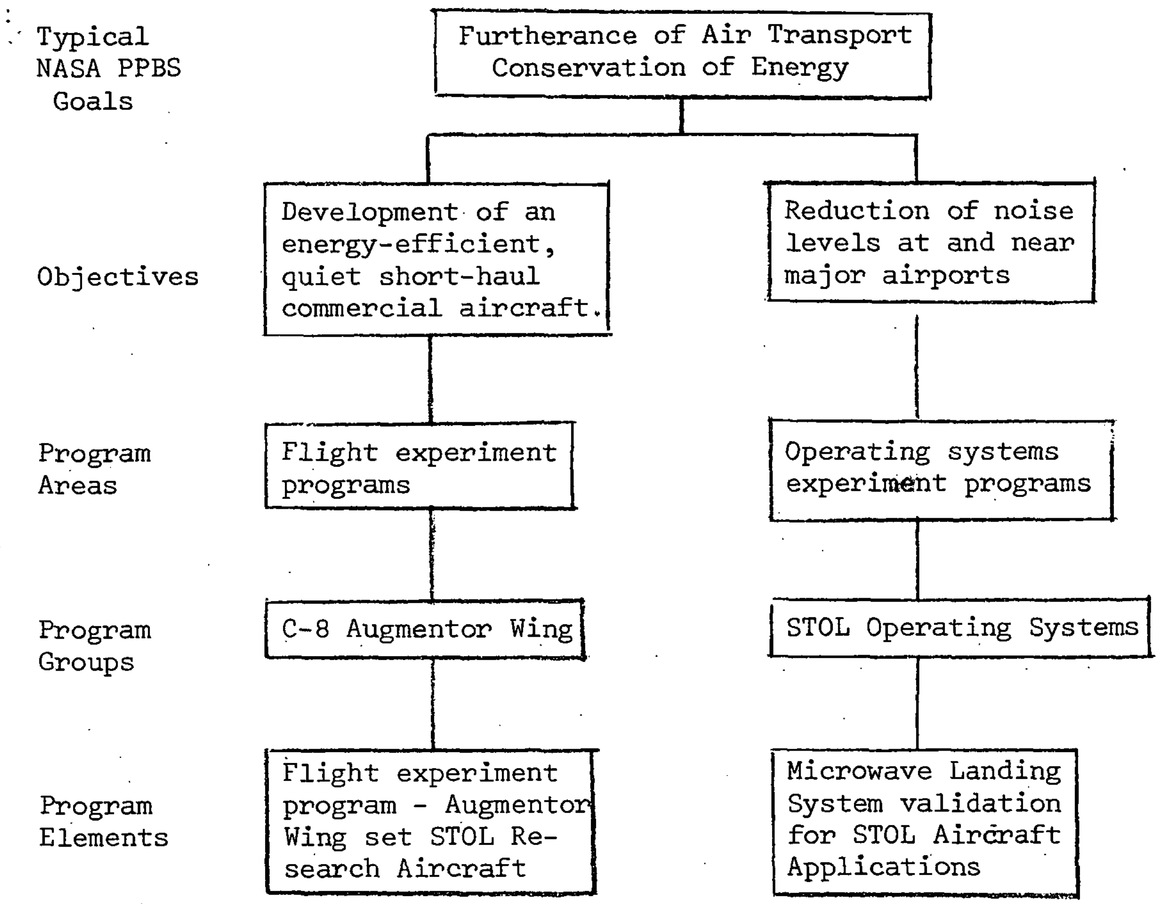


Figure 4

TYPICAL NASA PPBS STRUCTURE

areas for purposes of analysis. The Bayesian component of the model will deal with the short range aspects of the analysis, and the long range portion will be handled by the dynamic programming component.

The purpose of the Bayesian portion of the model is to determine the expected utility of proceeding with each R&D program area versus the expected utility of discontinuing the R&D effort in that program area. The implication of not proceeding further with R&D in a particular program area is either to shelve the particular technology it supports, or to implement the technology at its current level of development.

The analytic basis of this portion of the model lies in Bayesian Decision Theory, which is reviewed in detail in Volume I.[1] For purposes of this model, the Bayesian "experiments" are the program areas of civilian aviation Research and Development. The outcomes are descriptors of how well the research objectives have been met. The actions noted relate to management options with respect to the program area (i.e. continue study, shelve, implement). Finally, the states are composed of combinations of pertinent descriptors of external events of national significance which impact on the program area. These Bayesian components are summarized in Table 12.

As stated previously, the Bayesian component of the model simply

TABLE 12

BAYESIAN COMPONENTS FOR PROGRAM AREA ANALYSIS

Experiments	- Program Areas (e.g. Flight Experiment Programs)
	- Null (i.e. not funding the Program Area)
Outcomes	- Excellent results, meeting all research objectives
	- Good results, meeting some research objectives
	- Poor results, meeting few research objectives
Acts	- Shelve (i.e. discontinue work on the technology or program area)
	- Implement (e.g. Demonstration Project)
	- Continue Study (not applicable to the Null experiment)
States	- 1) National Economy - low unemployment Energy climate - stable with new sources forthcoming R&D Climate - perceived need for long term solutions
	- 2) National Economy - low unemployment Energy Climate - increasing supply (new technology) R&D Climate - perceived need for long term solutions
	- 3) National Economy - recession Energy Climate - stable, with new sources forthcoming R&D Climate - perceived need for short-term solutions
	- 4) National Economy - low growth Energy Climate - crisis situation R&D Climate - perceived need for short-term solutions

compares the expected utility of carrying out the program area to the utility of not doing so. Discussion will follow in the section on sample calculation with respect to the estimation of utilities and probability inputs for analysis. It should be noted that the null experiment precludes any outcomes and proceeds directly to an action choice and resulting state, as shown in Figure 5, a typical decision tree for one program area.

The process used in the evaluation model contains two steps. In the first step contained in the Bayesian submodel, each of the program area "experiments" are evaluated against their respective null experiments. Next, those experiments whose expected utility values are greater than their null experiments' expected values are ranked in order of declining expected value. From among these, several combinations can be constructed whose total monetary costs do not exceed the budget available for the time period. Several of these mutually exclusive bundles can then be evaluated as alternative research packages.

Using the above output, the second step articulates the dynamic programming submodel. This submodel takes the mutually exclusive alternative bundles of program areas and analyzes them within a traditional dynamic programming format. The theoretical and computational aspects of dynamic programming are discussed in Volume I, pp. 27-30.[2]

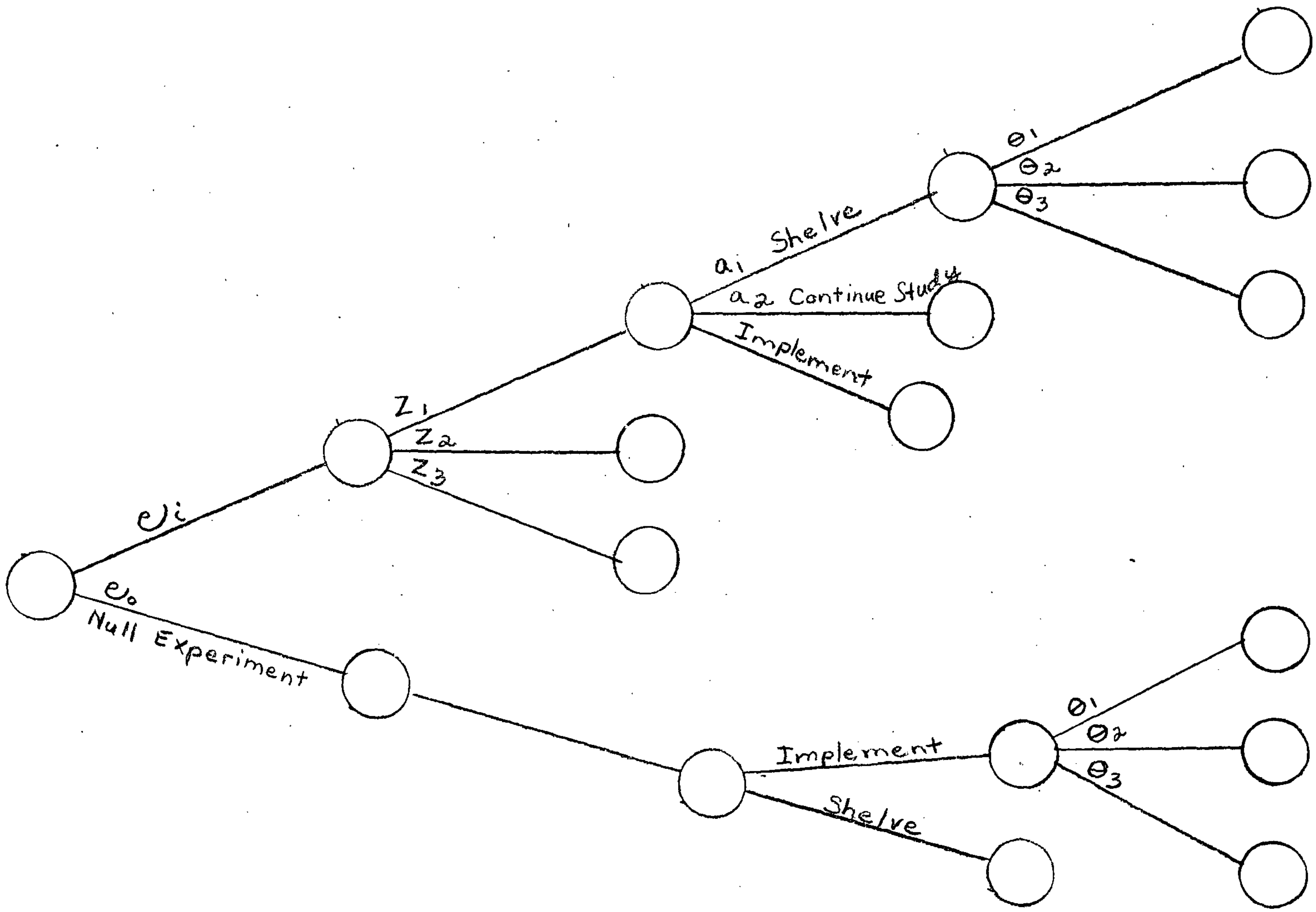


Figure 5

PROGRAM AREA DECISION TREE

The stages for analysis used herein correspond to 5 year planning periods, and the various states within each stage are, as shown in figure 12, possible composite descriptors of the national economy, the research state-of-the-art, the energy climate and other relevant items impacting the decision environment. The values assigned for transitioning from a given state at the present stage to some state at the next stage are based on the utility of the bundle derived in the Bayesian submodel. Since it is felt that this utility is not known with certainty, a probability distribution is attached to the transition utility.

Another important aspect of the above mentioned dynamic programming network is the existence of multiple termination states at the end of four stages or twenty years. In reality, there will be several ending states accessible from the states at the previous stage. For purposes of analysis, however, one most desirable state, that which most closely relates the agency's long term goal statements, will be chosen to conform to the dynamic programming solution algorithm. The resultant output from the dynamic programming submodel is an optimal path of R&D activities from each state to the terminal state, such as that subsequently to be discussed with respect to Figure 5.

Sample Problem - Source and Nature of Inputs

The source and nature of model inputs is worthy of discussion within the context of a sample problem which structures the solution of NASA Research and Technology Operating Plans (RTOP) in the short and long run. The program elements of the RTOP serve as the basic data unit. They contain the technical objectives and funding information necessary for evaluation. The RTOP program elements also denote the funding of individual elements for several fiscal years, including the previous, the present and several future years in some cases.

A critical set of inputs to the Bayesian submodel are the conditional probabilities of the experimental outcomes, $P(Z|E,S)$, which is the probability that outcome Z will be observed from experiment E if state S is the true state of the system. These probabilities are subjectively estimated by the decision-maker based on monitoring, experience and historical information about the RTOP program elements in an RTOP program area. Likewise, a second set of inputs to the Bayesian submodel are the a priori, or prior, probabilities of a state of the system obtaining. These probabilities are also subjectively estimated by the decision-maker, based on his knowledge and information on national issues and legislative strategies. The computer program which performs the Bayesian computations allows the decision-maker to quickly and easily modify these probabilities for

sensitivity analysis, reflecting actual or potential changes in national issues which could impact Research and Development endeavors.

The final set of inputs to the Bayesian submodel are the utility estimates for each of the paths in the Bayesian decision tree. These estimates represent the relative desirability of following a given path of experiment, outcome, action and resulting state in the decision tree. The method chosen to estimate these utilities is a slight modification of net benefits cash flow analysis. The decision-maker estimates the discounted dollar costs of each program area and then estimates the expected discounted dollar gain from each outcome-action-state path. The difference between these two is the utility of a given path. For the null experiment the decision-maker estimates the discounted dollar savings of not carrying out the program and the discounted opportunity costs for each action-state path (there are no outcomes since this is not an experiment in the Bayesian sense). The difference of these two in each case yields the utility for each path in the null experiment path set of the tree.

The sample problem analysis shown below will consist of considering three program areas and their null experiment counter-parts. In Table 13 we show the estimated five year costs of the program areas for sample program areas E_1 to E_3 which also become the cost savings for their null counter-parts E_{o1} to E_{o3}. As stated previously, these estimates

(Experiment)

RTOP No.	Program Area	Five Year Expenditure
768	1	22 million
769	2	27 million
743	3	8 million

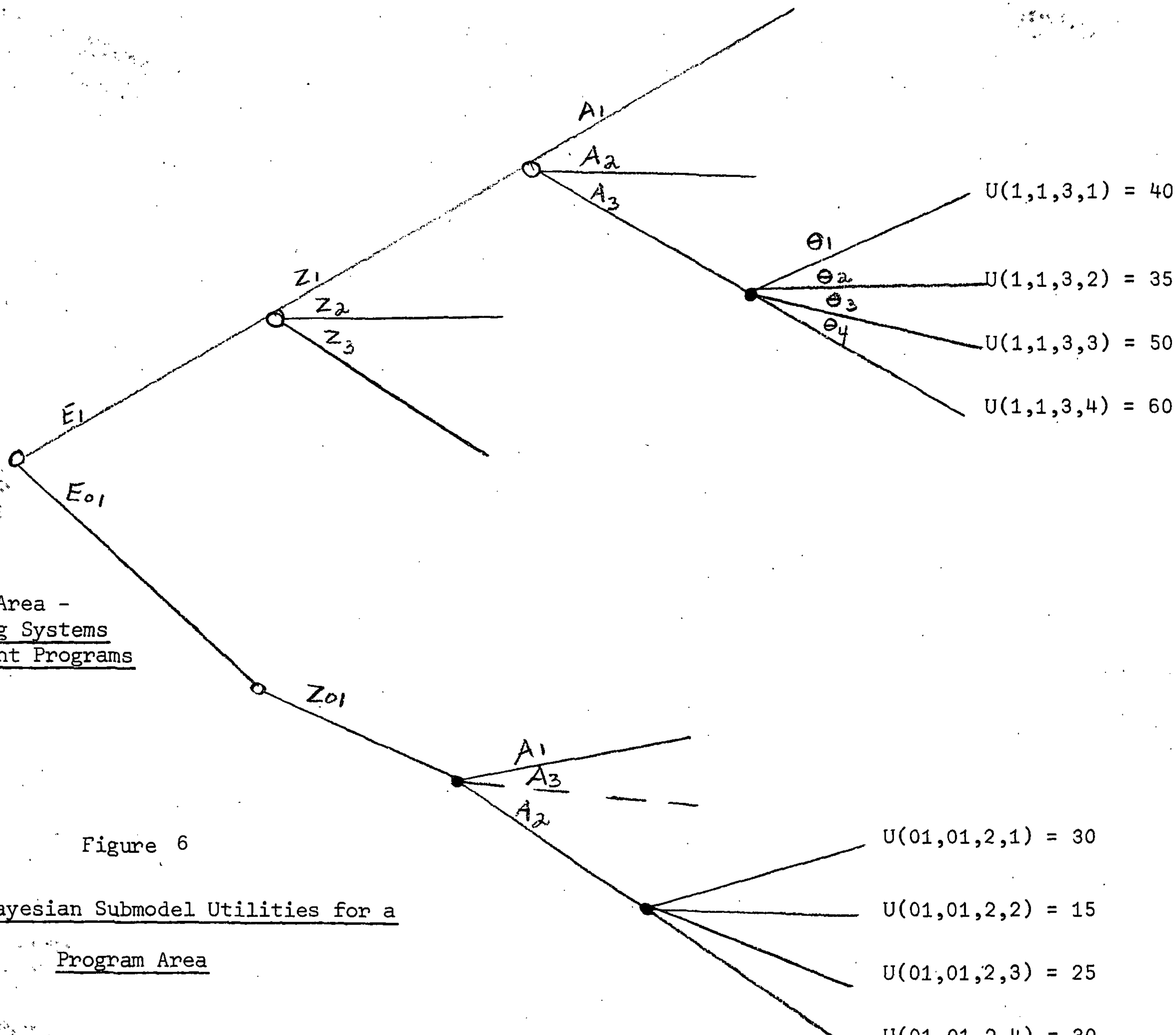
TABLE 13

ESTIMATED FIVE YEAR COSTS

OF EXAMPLE PROGRAM AREAS (EXPERIMENTS)

when combined with the estimates of dollar gain from executing the program area with a given outcome-action-state combination yields the utility of that path. On the null experiment set, the estimates of the cost savings are combined with the opportunity cost for an action-state path to yield a utility for the path, as shown in Figure 6. As a basis for the Bayesian computations, the various components for the entire set of three experiments, including estimates of the conditional probabilities P(Z|E,S), and prior probability P_i (θ) are tabulated in Appendix A. For purposes of notation, program area 1 will be noted as E_1 and its null counterpart E_{o1}, with like notation extending to the other two program areas as well.

The appropriate probability and utility input, in conjunction with output of the analysis are shown in Tables 14,15 and 16. The results in Table 14 indicate that experiment E_1(Operating Systems Experiments Programs) is dominant over experiment Eo_1 (the null counterpart). The indicated action under very good or fair results is to implement the technology and to shelve it under poor results. From the sensitivity analysis in Table 15 it appears that E_{O2} (the null experiment) is optimal over E_2 - Systems Technology Programs Quiet Propulsive Lift Technology,when the prior probability of state 1 occuring is high (above .5) and the others are uniformly low. Under these circumstances the dominant optimal action is to implement the technology. If the prior probability of state 1 is not high the



E_1 = Program Area -
<u>Operating Systems</u>
<u>Experiment Programs</u>

Figure 6

<u>Sample Bayesian Submodel Utilities for a</u>

<u>Program Area</u>

TABLE 14

RESULTS OF BAYESIAN ANALYSIS

E_1 vs. E_{o1}

PRIOR PROBABILITY ESTIMATES				EXPECTED REWARD	OPTIMAL ACTION FOR OUTCOME			OPTIMAL EXPERIMENT
θ_1	θ_2	θ_3	θ_4		Z_1	Z_2	Z_3	
.4	.2	.2	.2	46	3	3	1	1
.6	.2	.1	.1	43	3	3	1	1
.8	.1	.05	.05	42	3	3	1	1
.9	.05	.03	.02	41	3	3	1	1
.4	.3	.15	.15	45	3	3	1	1
.05	.85	.05	.05	43	3	3	1	1
.05	.05	.85	.05	49	3	2	1	1
.05	.05	.05	.85	54	3	3	1	1
.1	.1	.4	.4	50	3	3	1	1

E_1 - Program Area
Operating Systems
Experiment Programs

TABLE 15

RESULTS OF BAYESIAN ANALYSIS

E_2 VS. E_{o2}

PRIOR PROBABILITY ESTIMATES				OPTIMAL EXPERIMENT	EXPECTED REWARD	OPTIMAL ACTION FOR OUTCOME		
θ_1	θ_2	θ_3	θ_4			Z_1	Z_2	Z_3
.25	.25	.25	.25	1	35	3	1	1
.6	.15	.15	.15	2	39	1	1	1
.75	.1	.1	.05	2	42	1	1	1
.05	.85	.05	.05	1	37	3	3	1
.05	.05	.85	.05	1	37	3	1	1
.05	.05	.05	.85	1	38	1	1	1
.1	.1	.1	.7	1	37	1	1	1
.1	.1	.7	.1	1	37	3	1	1
.1	.7	.1	.1	1	37	3	3	1
.7	.1	.1	.1	2	41	1	1	1
.4	.2	.2	.2	1	36	3	3	1
.5	.15	.15	.2	2	37	1	1	1
.2	.4	.2	.2	1	35	3	1	1
.2	.2	.4	.2	1	36	3	1	1
.2	.2	.2	.4	1	34	3	1	1

E_2 - Systems Technology Programs - Quiet Propulsive Lift Technology

TABLE 16

RESULTS OF BAYESIAN ANALYSIS

E_3 VS. E_{o3}

PRIOR PROBABILITY ESTIMATES				OPTIMAL EXPERIMENT	EXPECTED REWARD	OPTIMAL ACTION FOR OUTCOME		
Θ_1	Θ_2	Θ_3	Θ_4			Z_1	Z_2	Z_3
.25	.25	.25	.25	2	59	1	1	1
.85	.05	.05	.05	2	56	1	1	1
.05	.85	.05	.05	2	60	1	1	1
.05	.05	.85	.05	2	64	1	1	1
.05	.05	.05	.85	2	56	1	1	1
.1	.1	.1	.7	2	57	1	1	1
.1	.1	.4	.4	2	60	1	1	1
.4	.1	.1	.4	2	57	1	1	1

E_3 - Supersonic Cruise Aircraft Research

optimal experiment becomes E_2 and the predominant optimal course of action is to implement the technology if the results are very good and to shelve it otherwise. In Table 16, E_{03}, the null experiment, dominates E_3, Supersonic Cruise Aircraft Research, over all estimates of the priors. The indicated action is to implement the technology.

The final phase of this sample problem inputs the Bayesian submodel output for five year periods into the long range (20 year) format of the dynamic programming submodel. The arcs between state 0 at stage 0 and states 1, 2 and 3 at stage 1 in figure 8 represent different possible bundles of program areas. For purposes of this analysis it will be assumed that one can represent several relevant versions of an entire R&D program on these arcs. For computational purposes, use will be made of the utilities from the three experiments and their null counterparts generated previously. Each arc in the network represents a bundle of program areas carried out with technologies implemented or shelved.

It is accepted that the values, or utilities, of the arcs are not known with certainty. Therefore, each arc's value will actually be an expected value composed of estimated rewards of the bundle and their associated probabilities of occurance, as conceptualized in Figure 7. This is denoted as:

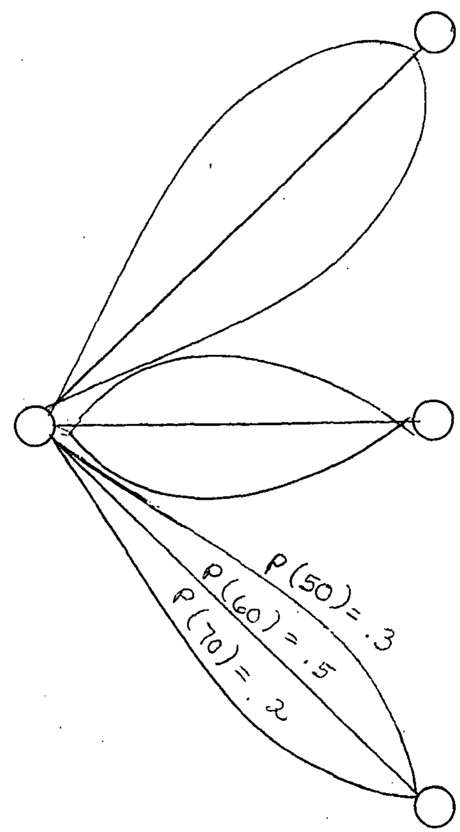


Figure 7

EXAMPLE OF STOCHASTIC DISTRIBUTION OF ARC UTILITIES

$Rij = \sum_a r_a P_a$, where Rij is the expected reward on the arc from state i to state j, r_a = a possible reward, and P_a = the probability of r_a.

As stated previously, the notion is introduced that there is a probability distribution on a state obtaining (i.e. a particular arc being taken). Therefore, the final utility on the arc will be the probability of the arc being taken times the expected reward of the arc discussed previously, denoted as:

$U_{ij} = P_{ij} R_{ij}$

where U_{ij} = the expected utility of the arc from state i to state j

P_{ij} = the probability of this transition from state i to state j occuring

R_{ij} = the expected reward on the arc, from state i to state j.

The computations will be carried out over five stages, or twenty years. Beyond State 1 the bundle values in the sample problem will be strictly hypothetical. However, the implication of going from stage 0 to stage 1 by one path has implications for the utilities of going from stage 1 to stage 2 over several paths. This concept has meaning in an R&D program,where expenditures in the present period may save money at some future point.

An additional adjustment which must be made for this application of dynamic programming deals with multiple ending states. As stated previously, normally, the solution technique for programming normally assumes a single ending state to the network. In this open-ended application, however, it is not realistic to assume this. Therefore, the solution will be found using only the state judged most likely to best reflect the agency's goal structure. Appropriate sensitivity analysis should involve separate solutions sets for several possible ending states.

The assumed twenty year network is shown in Figure 8 with the computed expected utilities. The arc probabilities, the expected rewards, and the final utilities are shown in Table 17. Performing dynamic programming analysis on the network in Figure 8 we arrive at a single optimal path through the network. This path includes states 0, 2, 4, 6 and 9. It yields a maximized expected utility of 133.75. A partial interpretation of this path could be continued study of microwave landing systems during the first stage followed by a demonstration in the second stage. In addition, it could represent first stage implementation of noise reduction procedures and continued study of airfoil shapes for three stages with demonstration occuring in the fourth stage.

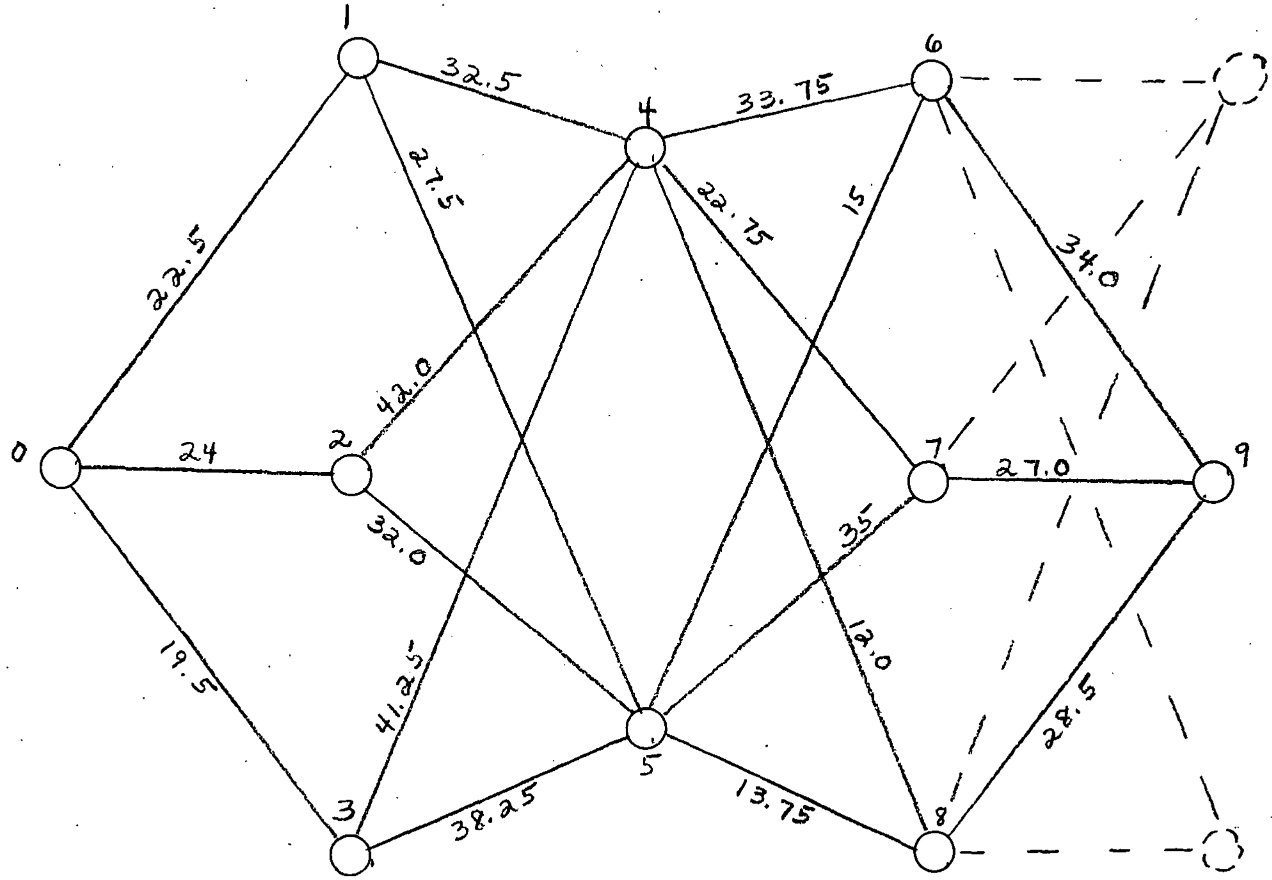


Figure 8

SAMPLE PROGRAM BUNDLE LONG TERM ANALYSIS

USING DYNAMIC PROGRAMMING

TABLE 17

SAMPLE PROGRAM BUNDLE UTILITIES FOR LONG TERM ANALYSIS

ARC P (STATE i, STATE j)	EXPECTED REWARD	PROBABILITY OF ARC	EXPECTED UTILITY
0,1	75	.3	22.5
0,2	60	.4	24
0,3	65	.3	19.5
1,4	65	.5	32.5
1,5	55	.5	27.5
2,4	70	.6	42.0
2,5	80	.4	32.0
3,4	75	.55	41.25
3,5	85	.45	38.25
4,6	75	.45	33.75
4,7	65	.35	22.75
4,8	60	.2	12.0
5,6	60	.25	15.0
5,7	70	.5	35.0
5,8	55	.25	13.75
6,9	85	.4	34.0
7,9	90	.30	27.0
8,9	95	.30	28.5

As stated previously, sensitivity analysis would reiterate the process with different terminal states and probability estimates for rewards and states.

Conclusions - Relevance of the Model

There are several concluding points with respect to this approach as applied to this example analysis:

1) The technique, although formatted for long range planning, has the capabilities to adapt readily to different conditions of R&D funding, energy outlook and other significant economic and national issues affecting the state space.

2) The technique has the capability of yielding an optimal path to the end of the network from any given state, further, the dynamic programming portion of the model, as well as the Bayesian submodel can be updated continuously by the decision-maker to reflect current thinking and events which may alter the validity of some of the stochastic or utility estimates.

The degree of subjectivity, and associated probabilistic inputs to the model insures that the decision-maker's knowledge of his R&D system and agency's operations, and historical R&D information will be appropriately used in the decision process. The formatting of such into a modelling framework allows orderly and informational use of relevant aspects of uncertainty and subjectivity to emerge in the decision process.

Finally, related to the above, the model is ideally suited to comprehensive sensitivity analysis on all prior and conditional probability inputs, and utilities, by utilizing a time-sharing interactive computer analysis as was performed for this example problem (see Appendix B for Software).

In summary, the approach offers the agency decision- maker the capability to efficiently test R&D policy evaluation over a highly flexible mix of information input, program bundle combinations, levels of uncertainty, and weighting of viewpoints which may be important to the policy maker in establishing Research and Development Program justification.

Footnotes Chapter III

1) Haefner, L.E., LOC. CIT. pp. 30-48.

CHAPTER IV

EXAMPLE PROBLEM - SCHEDULING OF RURAL COMMUTER SERVICE

INTRODUCTION - PROBLEM STRUCTURE

The objective of this example problem is to develop and demonstrate a scheduling analysis model for a rural regional air commuter system. Its financial feasibility is related to optimal employment of scheduling alternatives in light of the subsidy issue for commuter systems, and the travel demand characteristics of a sparsely populated rural region.

The regional scenario deals with commuter airports in communities or urbanized areas of ten thousand to fifty thousand people, oriented to intrastate travel. Urban areas of this size have quantitative and qualitative life style differences from larger metropolitan areas, and the airports and their impacts are significant in linking each of the communities as a functional place in the rural region. The air transportation system often serves as a catalyst for the community in attracting components of a strong economic base, i.e. business, industry and tourism, and provides a basis of connection of centers of government and finance with remote or isolated areas, allowing the entire region to operate in an integrated and functional manner.

Problem Inputs

The case study region selected for the example problem is the Idaho intrastate air transportation system. The current system is presented in Figure 9, with the further breakdown of the Idaho air transportation demand areas in Figure 10. This system has been discussed in detail in previous NASA research documents and the reader is so referred for a detailed description of the region.[1]

Analysis Approach

The analysis and evaluation of such an air transportation system can be undertaken by a Markovian Decision theory approach which involves the formulation of a state space, state transition probabilities and reward matrices for the system under study. The basic underlying concepts of Markovian Decision Theory are detailed in Volume I, with a brief mathematical treatment herein in Appendix C. The decision algorithm developed in the following pages makes use of Howard's Policy Iteration method for the determination of the steady state probabilities method, yielding an optimal scheduling alternative for commuter operation for the current travel demand status of the region. The formulation of the state space, associated transition and steady state probabilities,

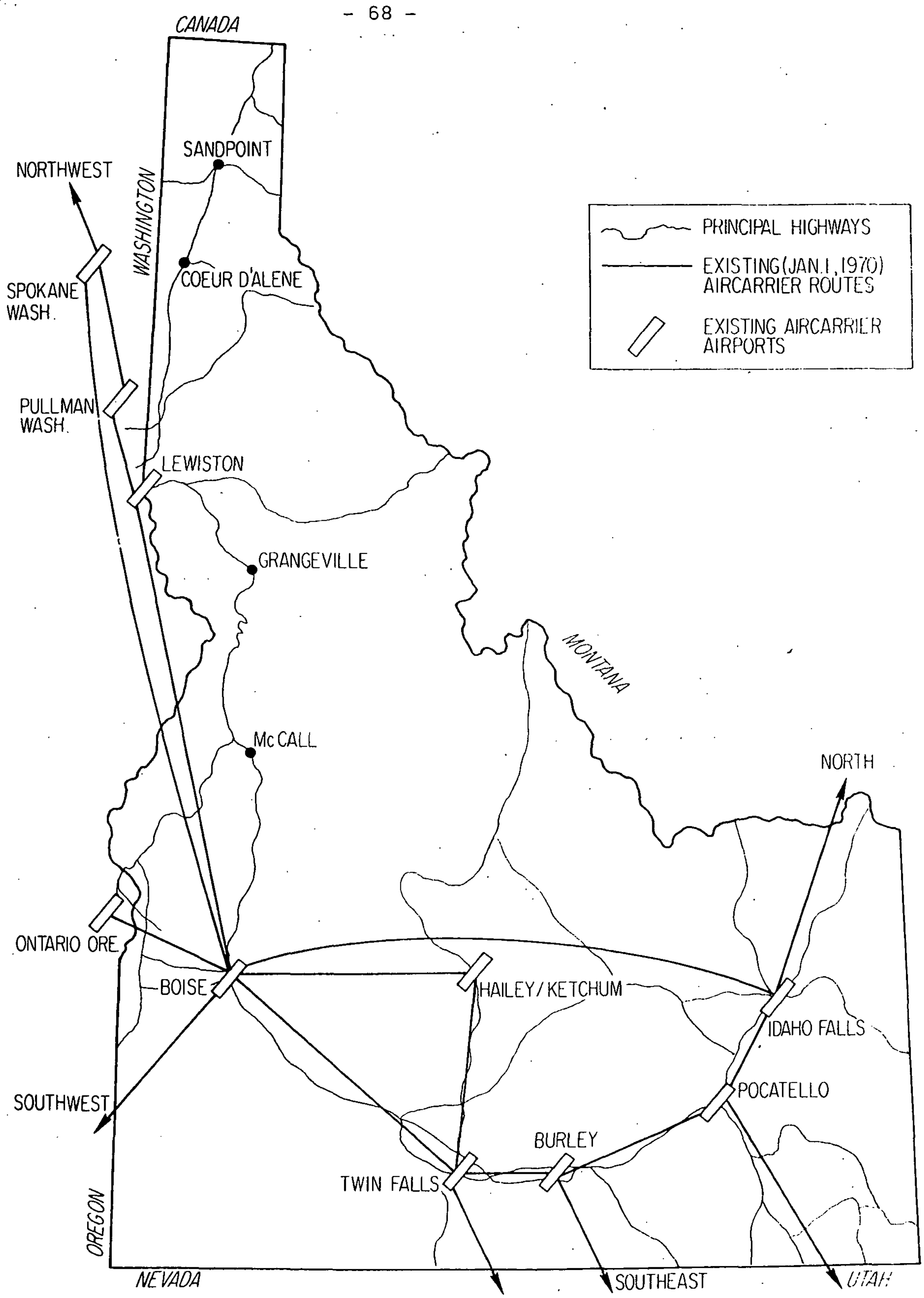


Figure 9 Current Idaho Transportation

Source: Figure 8-29, p. 8-75, "Western Region Short Haul Air Transportation Program, Definition Phase Report, Volume 2, Technical Report," The Aerospace Corporation, Air Transportation Program Office, July 1970.

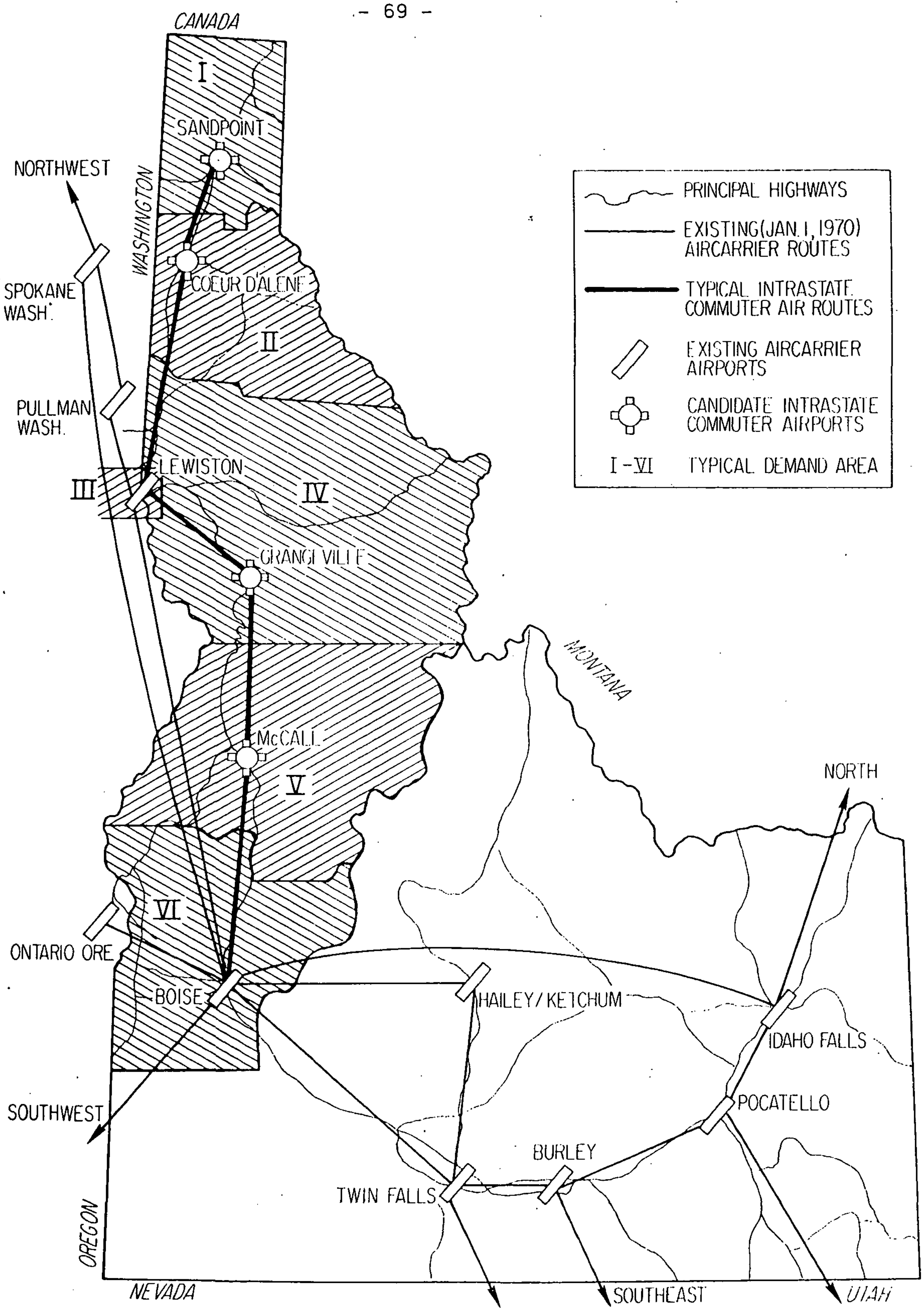


Figure 10 Idaho Intrastate Transportation Areas

Source: Figure 8-31, p. 8-79, "Western REgion Short Haul Air Transportation Program, Definition Phase Report, Volume 2, Technical Report," The Aerospace Corporation, Air Transportation Program Office, July 1970.

alternatives, reward matrices, and iteration results will now be discussed in detail.

Formation of State Space

The formulation of the system state space involved a review of the North-South travel corridor in Idaho and the classification of air transportation into two categories. In the first category, the commuter airports located in Sandpoint , Coeur D'Alene, Lewiston, Grangeville, McCall and Boise were selected as candidate intrastate commuter airports as shown in Figure 10. In the second category selected for analysis, airports were in a remote region air service in various cities 20 to 60 miles from the commuter hubs, and had a sufficient air travel demand. These remote region air service airport locations include the cities of Caldwell, Emmett, Weiser, Cambridge, Cascade, Council, Riggins, Kamiah, Pierce, Orofino, Craigmont, Elk River, Potlatch, Saint Maries, Avery, Kellogg, Clark Fork, Priest River and Bonners Ferry, and are shown in Figure 11. The selection criteria was based on the availability of travel demand data for further analysis, and the common criteria that all sites enveloped only one competing mode of transportation, a state highway within the study region shown in Figure 10. The travel patterns assumed a 50-50 directional split. Such projected Idaho intrastate air travel is presented in Table 18. Table 19 presents the estimated daily enplanements for the remote region service areas.

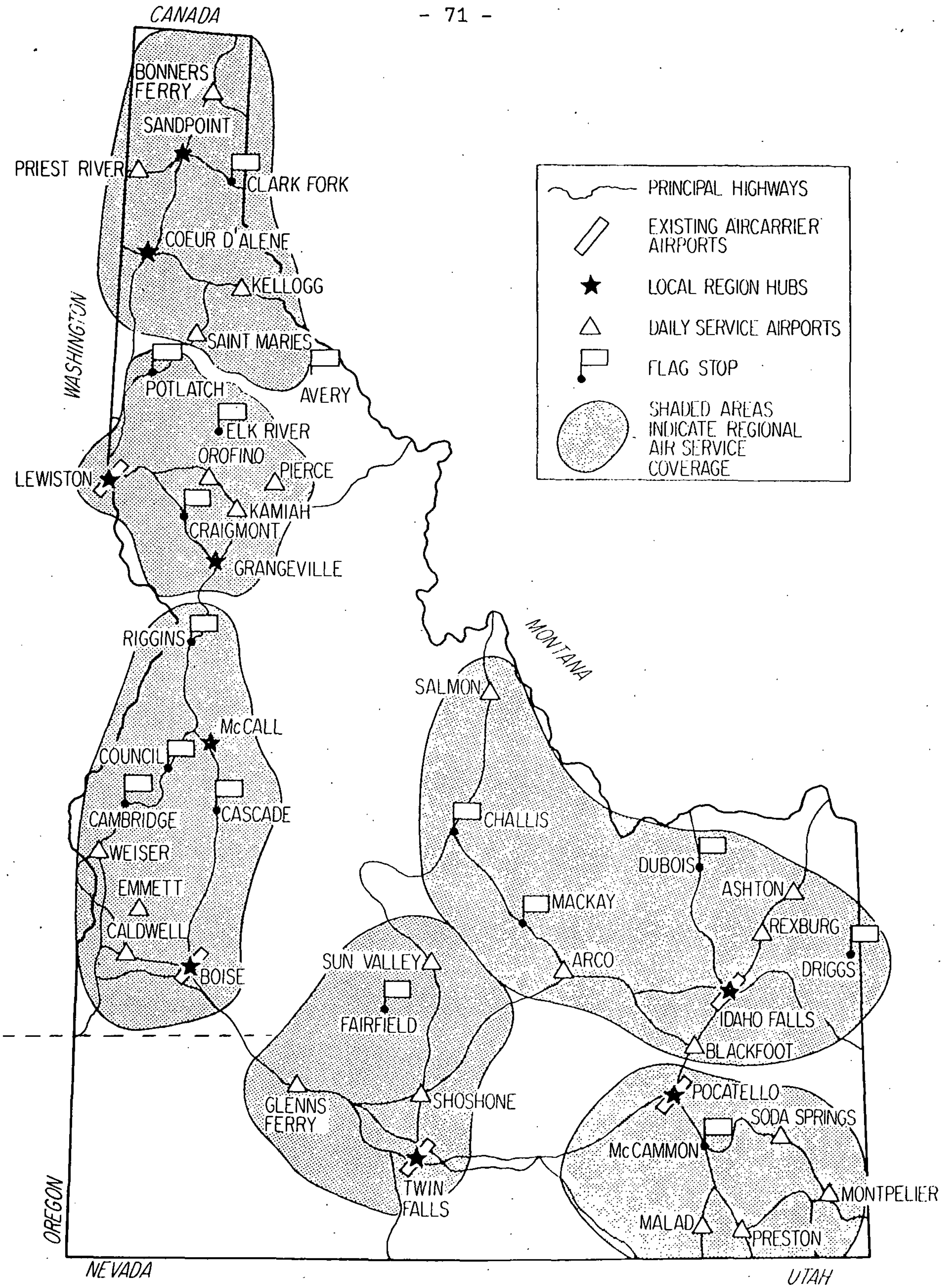


Figure 11 Idaho Remote Region Air Service

Source: Figure 8-30, p. 8-77, "Western Region Short Haul Air Transportation Program, Definition Phase Report, Volume 2. Technical Report," The Aerospace Corporation, Air Transportation Program Office, July 1970.

(ARIZONA) (COLORADO)

TABLE 18

TOTAL DAILY ORIGIN-DESTINATION DEMAND - COMMUTER REGION*

Daily Person Trips Air Mode (Two-way)

	Sandpoint 1	Coeur D'Alene 2	Lewiston 3	Grangeville 4	McCall 5
Coeur D'Alene 2	7				
Lewiston 3	7	16			
Grangeville 4	15	35	19		
McCall 5	4	7	10	17	
Boise 6	9	17	19	27	48

*Adapted from Figure 8-33, p.8-85, "Western Region Short Haul Air Transportation Program, Definition Phase Report, Volume 2, Technical Report," Aerospace Corporation.

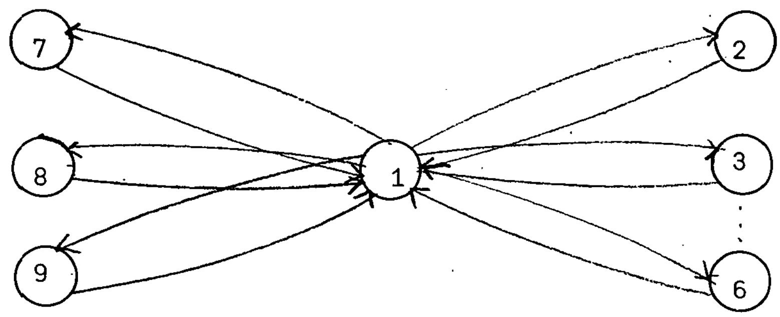
TABLE 19

REMOTE REGION AIR TRAVEL DEMAND*

STATE	SITE	ESTIMATED DAILY ENPLANEMENTS
1	Sandpoint Hub	
7	Bonners Ferry	2
8	Priest River	2
9	Clark Fort	½
2	Coeur D-Alene Hub	
10	St. Maries	2
11	Avery	½
12	Kellogg	4
3	Lewiston Hub	
13	Potlatch	1
14	Elk River	½
15	Craigmont	1
4	Grangeville Hub	
16	Orofino	4
17	Pierce	1
18	Kamiah	1
5	McCall Hub	
19	Riggins	½
20	Council	1
21	Cambridge	½
22	Cascade	1
6	Boise Hub	
23	Caldwell	8
24	Emmett	2
25	Weiser	3

* ibid.

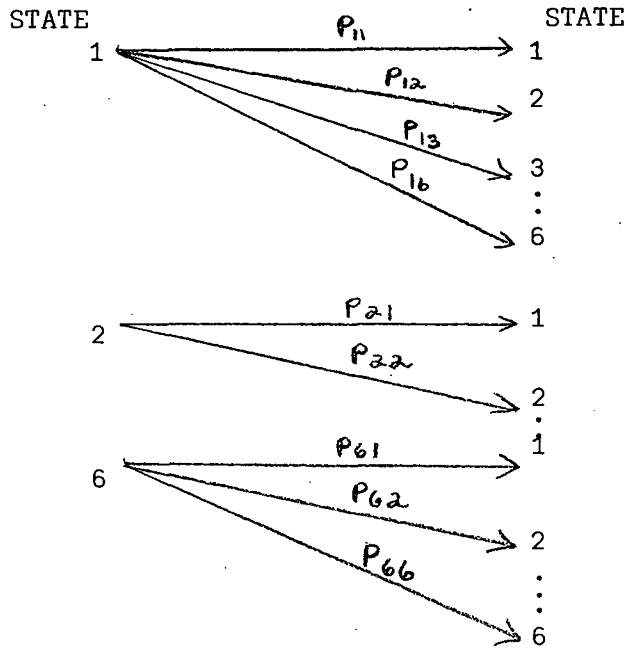
The transition state space can be schematically represented below for state 1. Here, state 1



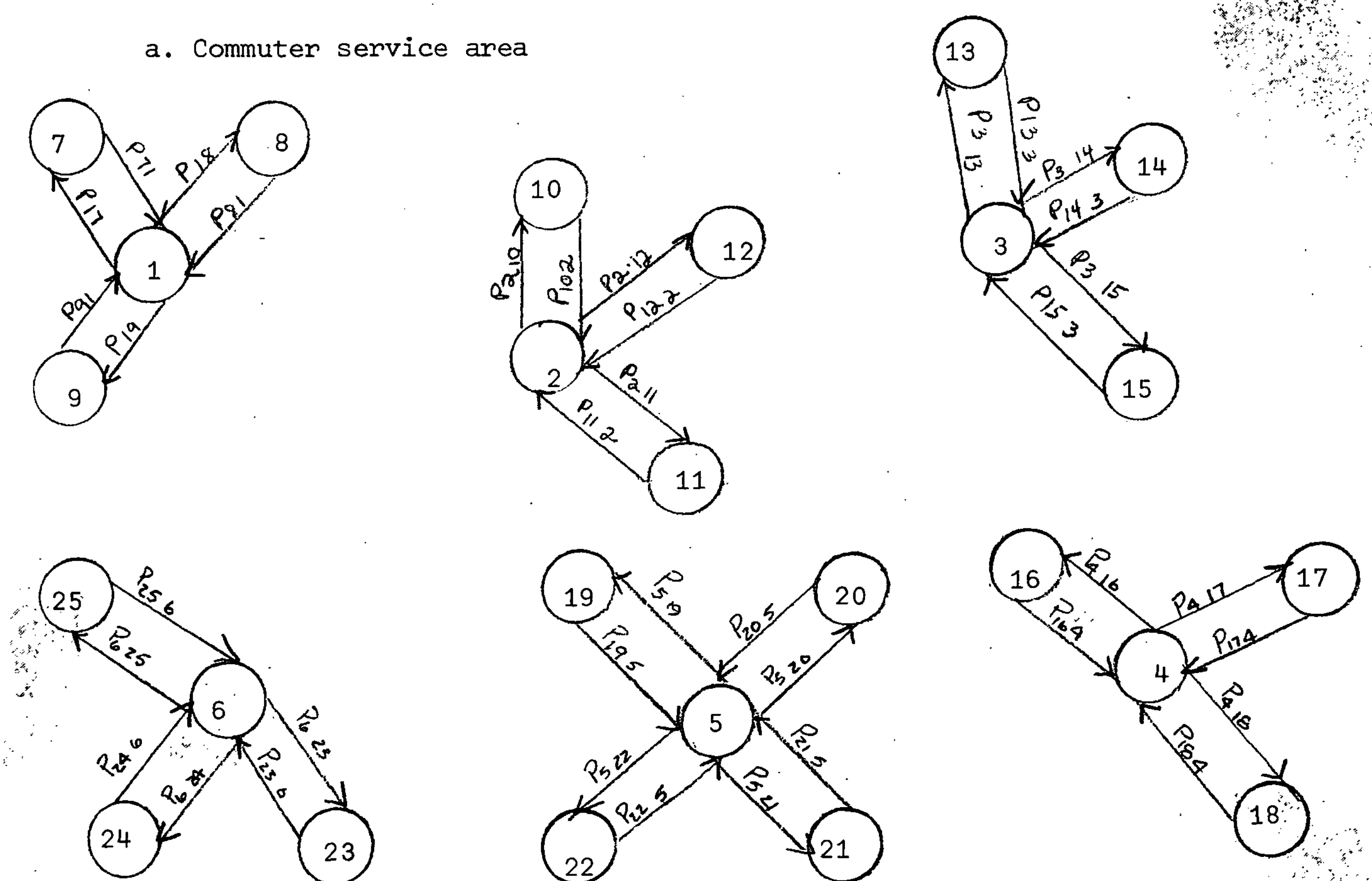
represents Sandpoint while 2 through 6 (commuter hubs) refer to Coeur D-Alene, Lewiston, Grangeville, McCall and Boise respectively. States 7 through 9 represent Bonners Ferry, Priest River, and Clarks Fork respectively which constitute the remote region serviced by the airport in Sandpoint. By a similar delineation, the entire state space is developed numbered and shown schematically in Figure 12. In effect, the Idaho air transportation system can be modeled as a multiple Markov chain. A traveler in the system may move from a remote region location only to the corresponding commuter hub, thus incurring a transition in locational state. The sequence of successive state transitions is viewed from the perspective of a passenger within the system selecting a destination j, give his origin at some state i. The transition probabilities are therefore $P(T_{ij}) = P_{ij}$ where $P(T_{ij})$ is the probability of a trip with a destination being state j given the passenger is now

Figure 12

STATE SPACE TRANSITIONS



a. Commuter service area



b. Remote service region

originating in state i. The values of the probabilities P_{ij} reflects the volume of trips from locational state i to locational state j relative to the total number of trips from state i to all states j within the system. Mathematically, $P(T_{ij}) = \frac{T_{ij}}{\sum_{j=1}^{m} T_{ij}}$

where

$P(T_{ij})$ = probability of a trip state i to state j

T_{ij} = total number of trips, state i to state j

m = number of destination states from i.

These transition probabilities are presented in Table 20.

Scheduling and Operation Alternatives

The formulation of the alternatives reflect options in alteration of service patterns and operations given the demand levels of the system. Alternative 1 includes 8 round trips per day between Boise and Coeur D'Alene. Four of these trips per day will continue to Sandpoint. In the remote service region, service would be on a demand responsive basis. Alternative 2 constitutes the same commuter hub service but the following pattern in the remote service region.

1. Sandpoint Hub

7. Bonners Ferry	AM, PM
8. Priest River	AM, PM
9. Clark Fork	demand responsive

TABLE 20

SINGLE STEP TRANSITION PROBABILITIES

STATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	.135	.118	.118	.255	.068	.153	.068	.068	.017																
2	.074	.289	.167	.368	.074	.179				.042	.011	.084													
3	.075	.171	.188	.203	.107	.203							.021	.011	.021										
4	.102	.238	.130	.251	.068	.130										.055	.013	.013							
5	.056	.099	.141	.239	.216	.380													.012	.023	.012	.023			
6	.042	.080	.090	.128	.228	.309																	.076	.019	.028
7	1.0																								
8	1.0																								
9	1.0																								
10		1.0																							
11		1.0																							
12		1.0																							
13			1.0																						
14			1.0																						
15			1.0																						
16				1.0																					
17				1.0																					
18				1.0																					
19					1.0																				
20					1.0																				
21					1.0																				
22					1.0																				
23						1.0																			
24						1.0																			
25						1.0																			

2. Coeur D'Alene Hub	
10. St. Maries	AM, PM
11. Avery	demand responsive
12. Kellogg	AM, Noon, PM
3. Lewiston Hub	
13. Potlatch	demand responsive
14. Elk River	demand responsive
15. Craigmont	demand responsive
4. Grangeville	
16. Orofino	AM, Noon, PM
17. Pierce	AM
18. Kamiah	AM
5. McCall	
19. Riggins	demand responsive
20. Council	demand responsive
21. Cambridge	demand responsive
22. Cascade	demand responsive
6. Boise Hub	
23. Caldwell	4 flights daily
24. Emmett	AM, PM
25. Weiser	AM, Noon, PM

Alternative 3 has 8 flights per day from Boise to Sandpoint with a demand responsive service to the remote region. Alternative 4 has 8 round trip flights also, but with the scheduled remote region service presented above for alternative 2. Demand responsive service indicates service as needed for passengers at the requested location within a period of time which fits into the air commuter's overlying basic schedule for hub operation.

Development of Reward Matrices

The reward matrices for the system state transitions reflects the air fares, direct and indirect operating costs, and potential of available subsidies from any source. The air fares were calculated as a function of stage length from Figure 13, and are presented in Table 21. Direct operating costs relfect crew pay, purchase cost of aircraft, insurance, fuel, and maintenance costs. The procedure for this DOC calculation is outlined in Appendix D. Indirect operating costs were calculated as a function of stage length from Figure 14. The total of these costs for the above various transportation scheduling alternatives is used in Tables 22 through Table 25. These calculations assume an interest rate of 12% and project life of 20 years in calculating annual cash flows, and a value of time of $10.00 per hour in determining time penalties for different service patterns. The r_{ij}^k value is

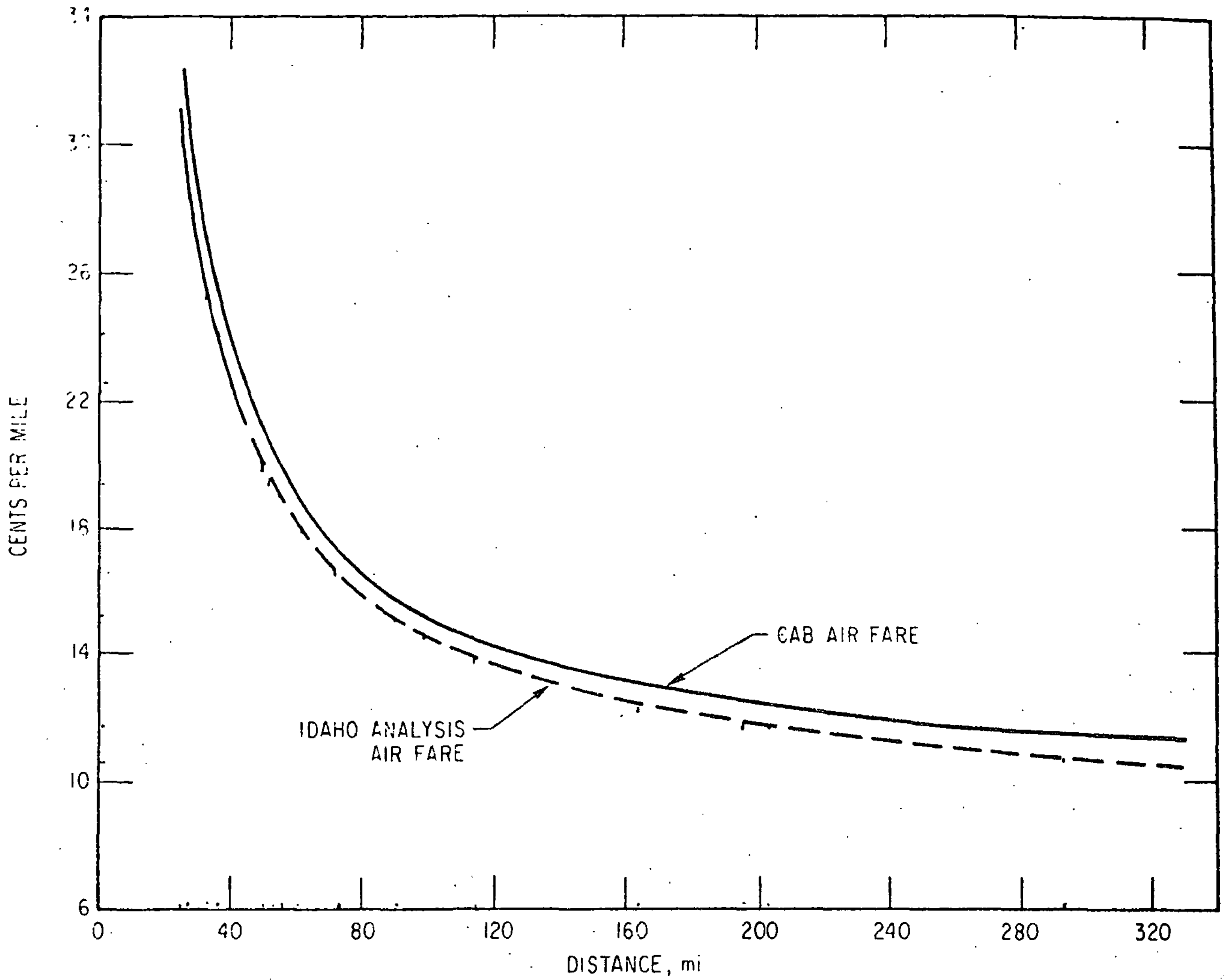


Figure 13 Air Taxi Fares (Including Taxes)

Source: Figure 8-32, p. 8-84, "Western Region Short Haul Air Transportation Program, Definition Phase Report, Volume 2, Technical Report," The Aerospace Corporation, Air Transportation Program Office, July 1970.

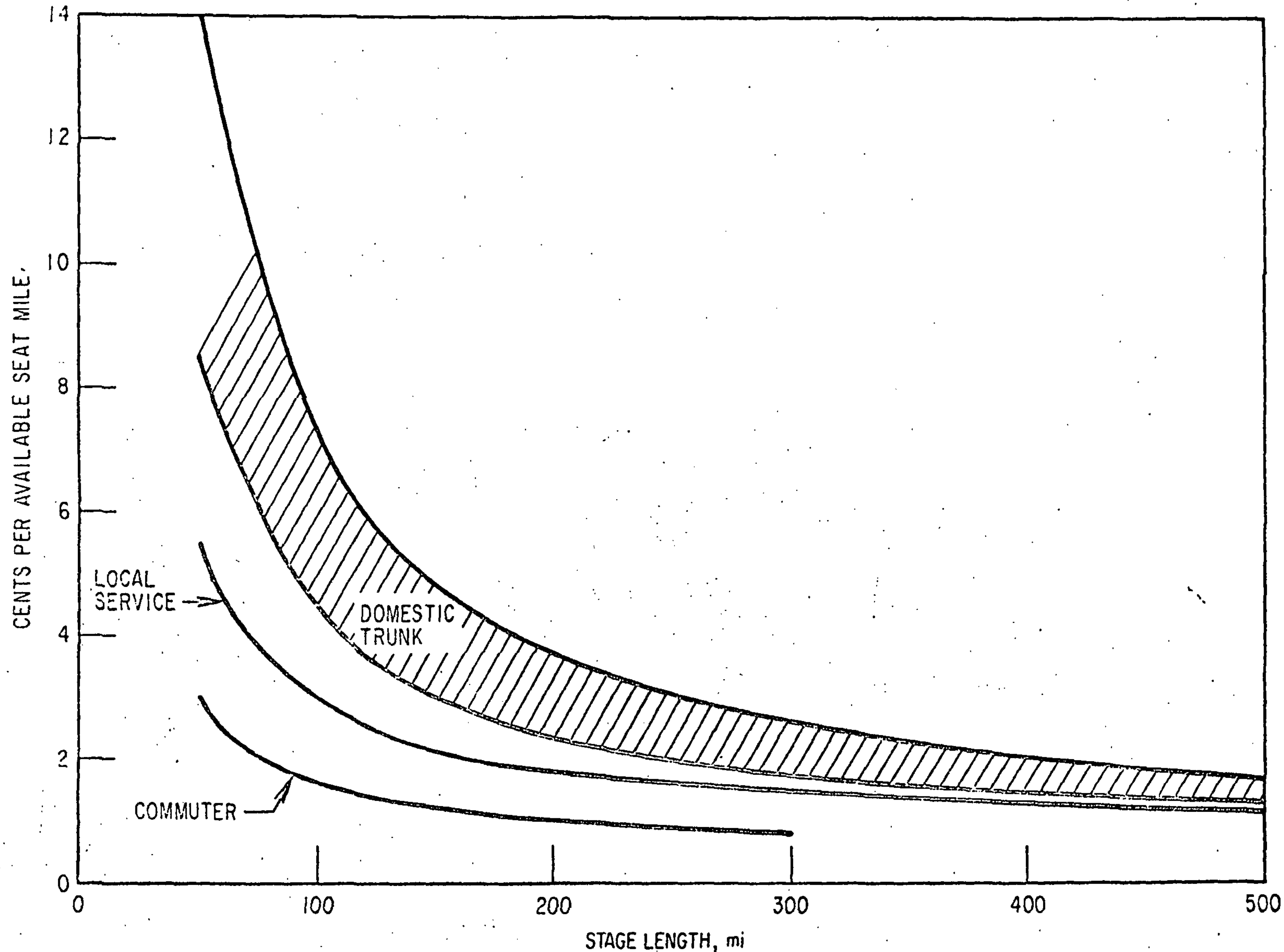


Figure 14 **Indirect Operating Costs**

Source: Figure 6-5, P. 6-8, "Western Region Short Haul Air Transporation Program, Definition Phase Report, Volume 2, Technical Report," The A[illegible] Corporation, Air Transportation Program Office, July 1970

TABLE 21

ACTUAL AIR FARES - ONE WAY

LOCATIONAL STATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	8.95	17.85	21.00	26.70	34.50	8.35	6.00	6.60																
2	8.95	0	14.40	17.60	23.80	31.15				8.35	10.80	8.55													
3	17.85	14.40	0	10.50	15.70	23.40							9.05	10.00	8.05										
4	21.00	17.60	10.50	0	12.00	20.50										9.05	9.15	6.00							
5	26.70	23.80	15.70	12.00	0	13.60													9.05	6.00	8.40	8.05			
6	34.50	31.15	23.40	20.50	13.60	0																	7.50	7.50	10.80
7	8.35						0																		
8	6.00							0																	
9	6.60								0																
10		8.35								0															
11		10.80									0														
12		8.55										0													
13			9.05										0												
14			10.00											0											
15			8.05												0										
16				9.05												0									
17				9.15													0								
18				6.00														0							
19					9.05														0						
20					6.00															0					
21					8.40																0				
22					8.05																	0			
23						7.50																	0		
24						7.50																		0	
25						10.80																			0

TABLE 22

REWARD MATRIX, ALTERNATIVE 1

STATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	2.22	9.69	11.68	15.95	22.49	-1.94	-2.75	-2.41																
2	2.37	0	9.07	11.12	15.87	21.97				-1.79	-2.00	-1.87													
3	9.80	9.03	0	5.40	9.16	15.60							-2.19	-2.54	-1.63										
4	11.87	11.14	5.47	0	6.69	13.93										-1.98	-2.64	-2.57							
5	16.37	15.85	9.18	6.64	0	8.42													-3.05	-2.82	-3.92	-1.73			
6	22.68	22.01	15.69	13.95	8.49	0																	-1.71	-1.71	-1.89
7	-2.14						0																		
8	-2.95																								
9	-11.56																								
10		0.77																							
11		-11.30																							
12		-4.35																							
13			-6.71																						
14			-3.29																						
15			-1.90																						
16				-4.49																					
17				-7.23																					
18				-2.91																					
19					-10.64																				
20					-6.52																				
21					-13.20																				
22					-2.02																				
23						0.80																			
24						-3.95																			
25						-5.31																			

TABLE 23

REWARD MATRIX, ALTERNATIVE 2

STATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	2.22	9.69	11.68	15.95	22.47	-11.62	-12.55	-12.19																
2	2.37	0	9.07	11.12	15.87	21.97				-11.47	-8.90	-8.51													
3	9.80	9.03	0	5.40	9.16	15.60							-1179	-12.04	-11.60										
4	11.87	11.14	5.47	0	6.69	15.93										-7.93	-12.23	-12.37							
5	16.37	15.85	9.18	6.64	0	8.42													-12.65	-12.62	-13.57	-11.05			
6	22.68	22.01	15.69	13.95	8.49	0																	-4.96	-11.46	-8.82
7	-11.82																								
8	-12.75																								
9	-21.34																								
10		-8.91																							
11		-18.20																							
12		-10.50																							
13			-16.31																						
14			-12.79																						
15			-11.87																						
16				-10.94																					
17				-16.82																					
18				-12.71																					
19					-20.24																				
20					-16.32																				
21					-22.85																				
22					-11.74																				
23						-2.45																			
24						-13.7																			
25						-12.24																			

TABLE 24

REWARD MATRIX, ALTERNATIVE 3

STATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	-1.54	6.03	8.02	12.28	18.82	-1.94	-2.75	-2.41																
2	-1.29	0	9.07	11.12	15.87	21.97				-1.79	-2.00	-1.87													
3	6.14	9.03	0	5.40	9.16	15.60							-2.19	-2.54	-1.63										
4	8.20	11.14	5.47	0	6.69	13.93										-1.98	-2.64	-2.57							
5	12.41	15.85	9.18	6.64	0	8.42													-3.05	-2.82	-3.92	-1.73			
6	19.02	22.01	15.69	13.95	8.49	0																	-1.71	-1.71	-1.89
7	-2.14																								
8	-2.95																								
9	-11.56																								
10		0.77																							
11		-11.30																							
12		-4.35																							
13			-6.71																						
14			-3.29																						
15			-1.90																						
16				-4.49																					
17				-7.23																					
18				-2.91																					
19					-10.64																				
20					-6.52																				
21					-13.20																				
22					-2.02																				
23						0.80																			
24						-3.95																			
25						-5.31																			

TABLE 2[illegible]

REWARD MATRIX, ALTERNATIVE 4

STATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	0	-1.54	6.03	8.02	12.28	18.82	-11.62	-12.55	-12.19																
2	-1.29	0	9.07	11.12	15.87	21.97				-11.47	-8.90	-8.51													
3	6.14	9.03	0	5.40	9.16	15.60							-11.79	-8.90	-8.51										
4	8.20	11.14	5.47	0	6.69	13.93										-7.93	-12.23	-11.60							
5	12.41	15.85	9.18	6.64	0	8.42													-12.65	-12.62	-13.57	-11.05			
6	19.02	22.01	15.69	13.95	8.49	0																	-4.96	-11.46	-8.82
7	-11.82																								
8	-12.75																								
9	-21.34																								
10		-8.91																							
11		-18.20																							
12		-10.50																							
13			-16.23																						
14			-12.79																						
15			-11.87																						
16				-10.44																					
17				-16.82																					
18				-12.71																					
19					-20.24																				
20					-16.32																				
21					-22.85																				
22					-11.74																				
23						-2.45																			
24						-13.70																			
25						-12.24																			

the monetary reward per enplanement accruing to the system operation for the passenger trip from state i to state j while the commuter system is employing scheduling alternative k.

Analysis

Markovian Decision analysis is an iterative solution process based on an efficient algorithmic investigation of long run gains to the system under study. The solution is arrived at via the policy iteration method outlined in Appendix C, which yields an optimal alternative for each state of the system. The compendium of these state-specific optimal alternatives is termed the policy vector. In this specific example, however, each state is a location of origin or destination, and a transition from i to j denotes a completed person-trip from location i to location j. As such, solution requires the specification of an alternative which maximizes the gain to the system over the long run demand characteristics of the entire set of locations. This gain g, is defined as:

$$g^{k*} = \max_{k} \sum_{i=1}^{N} \pi_i \, Q_i^{k}$$

where π_i is the vector of steady state probabilities, an example of which is shown in Table 26, and computed as demonstrated in Appendix C. These are the long run average fraction of total system

Table 26

STEADY STATE PROBABILITIES

STATE	π_i
1	.0688
2	.1594
3	.1196
4	.2104
5	.1228
6	.2259
7	.0047
8	.0047
9	.0012
10	.0053
11	.0014
12	.0104
13	.0025
14	.0013
15	.0025
16	.0116
17	.0027
18	.0027
19	.0015
20	.0028
21	.0015
22	.0028
23	.0171
24	.0043
25	.0121

person-trip origins which emanate from location i at any time t. Q_i^k is the expected immediate reward as denoted in Appendix C. This long run gain g, can be operationally defined as the reward to the system operation in dollars per enplanement.

Conclusions

The values of g for the various alternatives are presented in

Table 27 Long Run System Gain, g

Alternative k	g^k
1	-5.0820
2	-5.5347
3	-4.8353
4	-5.2599

($ per enplanement)

Table 27. In terms of the system description and problem inputs herein, the system obtains a loss over all scheduling alternatives reviewed. In light of this, rather than review and develop other alternatives, the research team decided to investigate the subsidy issue by applying a sensitivity analysis to the above losses over a range of subsidies, in terms of lump sum percentage of total capital and operating cost required to be subsidized to yield a break-even point in

TABLE 28

LONG RUN SYSTEM GAIN, g, WITH SUBSIDY

SUBSIDY LEVEL	ALTERNATIVE			
	1	2	3	4
0%	-5.0820	-5.5347	-4.8353	-5.2599
10%	-3.3296	-3.6262	-2.9756	-3.3814
20%	-1.5811	-1.7220	-1.1625	-1.5021
26.3%	-	-	0.0000	-
28.0%	-	-	-	0.0000
28.6%	0.0000	-	-	-
29.0%	-	0.0000	-	-

($ per enplanement)

operations. This subsidy may come from any source such as an additional statewide sales tax, a Federal subsidy, or local community support.

As can be seen in Table 28, Alternative 3 requires the minimum subsidy level for operation with 26% of system costs being assignable to subsidy sources. This is the scheduling alternative with eight round trips per day from Boise to Sandpoint and a demand responsive service in the remote region.

In concluding this example problem, it should again be noted that the advantage of using such a technique lies in the capability to perform meaningful sensitivity analysis. In this case, testing with respect to subsidy required against different alternatives. Optionally, the algorithm could have been employed to detail other, radically different scheduling and/or curtailment of service alternatives to test the resulting system gain. The issues of subsidy and/or curtailment of service and resultant regional impact have certain philosophical overtones, and will be explained further in light of this example problem, along with concluding comments about the analytic techniques in Chapter 6 of this volume.

FOOTNOTES

1 "Western Region Short-Haul Air Transportation Program, Definition Phase Report, Volume I, Demonstration Program Plan," E.R. Hinz, Director, Air Transportation Program, The Aerospace Corporation, July 1970.

"Western Region Short-Haul Air Transportation Program, Definition Phase Report, Volume II, Technical Report", Air Transportation Program Office, The Aerospace Corporation, July 1970.

CHAPTER V

CASE STUDY

INTRODUCTION

As stated in Chapter I, one of the objectives of the research is to test an evaluation issue in an actual case study setting, incorporating a realistic study scenario, actual data, and relevant performance indicators to the extent possible. As noted previously, the problem area chosen for case study was the planning implementation of STOL/VTOL programs in a metropolitan area. The metropolitan St. Louis Region was chosen as the case study area, due to the research team's familiarity with its transportation policy activities, their subjective feel for the decision-makers' and actor groups' response to public works investments having significant socio-economic-environmental impacts, and the detailed regional travel data bank developed for the region through the study team's previous professional activities. locally. As such, the issue of investigation is the marketing of STOL/VTOL facilities programs into the public works and private investment sectors of the region.

The decision process involved in the feasibility analysis, and the engineering and planning implementation of STOL/VTOL programs will be analytically modelled. The results of such modelling should yield information on:

1) An efficacious modelling and analysis framework for assessing feasibility of metropolitan oriented STOL/VTOL programs.
2) Some commentary on basic aspects of feasibility such as subsidy issues, integration with other land uses, strategic implementation considerations, etc.
3) A framework for justifying conclusions with respect to authorizing or rejecting facilities investments, in light of information yielded through (1) and (2) immediately above.

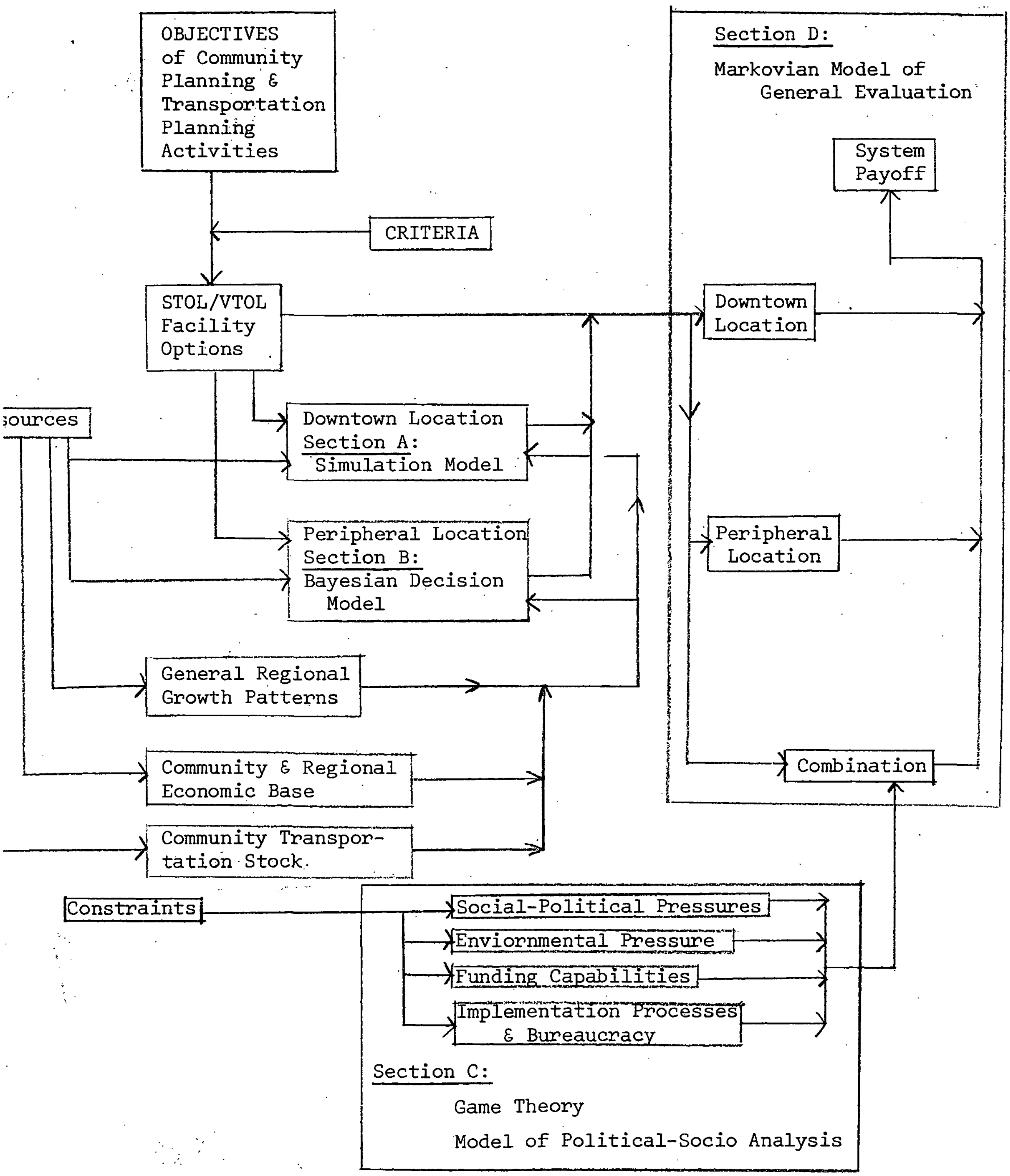
The chapter proceeds by developing an overview and logic structure for the case study, specific analysis of critical component sections, and conclusions with respect to items 1-3 above.

Overview of Case Study

The master logic for the case study is shown in Figure 15. It attempts to evaluate the feasibility and decision process of location of STOL/VTOL facilities in a metropolitan area. Typical improved mobility and quality of life objectives are assumed for

Figure 15

CASE STUDY MASTER LOGIC



the metropolitan land use and transportation planning process, in conjunction with typical performance criteria on travel time, degree of urban blight,etc. Against these bases for planning, the community exists in its present state with certain resources attached to its present growth pattern, its economic base, and its current stock of transportation facilities.

Given the above entities, certain options for STOL/VTOL facilities investment exist over the region, with varying degrees of feasibility. These include location in, or immediately adjacent to the downtown core, or a location on the urban periphery, or a combination of several peripheral locations and a downtown site, the latter concept bringing forth the notion of a STOL/VTOL system as a major competitor with other modes for all types of metropolitan and regional travel markets. All decisions on any of the above investment options will be met with varying levels of opposition, due to constraints emanating from socio-political pressures, actual or perceived environmental degradation, funding limitations, and the general bureaucracy of decision-making on major regional investments.

In light of the above, the following sections A through D attempt to develop analytic techniques for determining the location and investment feasibility of downtown and peripheral STOL options,

and yield information on critical aspects of the evaluation and implementation issues associated with the decision process. Section A develops a model of the feasibility of downtown location with respect to integration of the STOL/VTOL facilities with typical "downtown" activities, using a simulation model which depends heavily on regional travel behavior as input. Section B yields a modelling framework for analysis of STOL/VTOL locations on the periphery, developing the process through a statistical decision approach which utilizes critical information on the peripheral land use planning process. Section C, utilizing a modified game theoretic approach on the scenario in Section B, develops a framework for predicting location and development alternatives that are likely to be implemented, given the constraints and decision pressures in Figure 15. Section D develops a model of a regionwide STOL/VTOL investment strategy, as a viable component of the metropolitan multimodal transportation resources, treating long term regional growth, economic and transport investment patterns as a markovian decision process of adaptation to maximize long term regional planning objectives.

The St. Louis metropolitan area, as illustrated in succeeding figures, is an area of 2 million population, with a core which has declined in regional prowess over the last decade, but that is currently undergoing substantive revitalization as an anchor in the

region due to a surge of commercial, hotel and office construction activity. The suburban area is largely sprawled, with a recognizable auto dominant type of traveler behavior. Several options for regional transportation investment exist, as will be examined in the succeeding discussion.

SECTION A - FEASIBILITY OF DOWNTOWN STOL/VTOL FACILITIES

Modelling Strategy

This section develops a simulation model to test the efficacy of situating a STOL/VTOL facility in, or strategically adjacent to the downtown core. It is designed to test the exploitation of downtown hotel, commercial, and rail and bus terminal activities when contiguously joined with a STOL facility, as a "transportation center". The objective is to assemble a set of travel uses the downtown-oriented traveler would be inclined to use as a package, either as a metropolitan commuter, or an interegional traveler requiring change of mode facilities immediately adjacent to commercial and office activities. The focus of the model is to test for fare structure, subsidy and daily frequency of flights required to allow the STOL facility operation to recover its capital and operating cost of existence. The model makes use of several entities of travel behavior, modal split, land acquisition, maintenance and capital recovery factors which have been documented in recent NASA studies as inputs to the simulation. For purposes of analysis, a study site in downtown St. Louis was picked to exist at either A or B, in Figure 16.both of which are deemed feasible from air traffic control standpoint.[1]

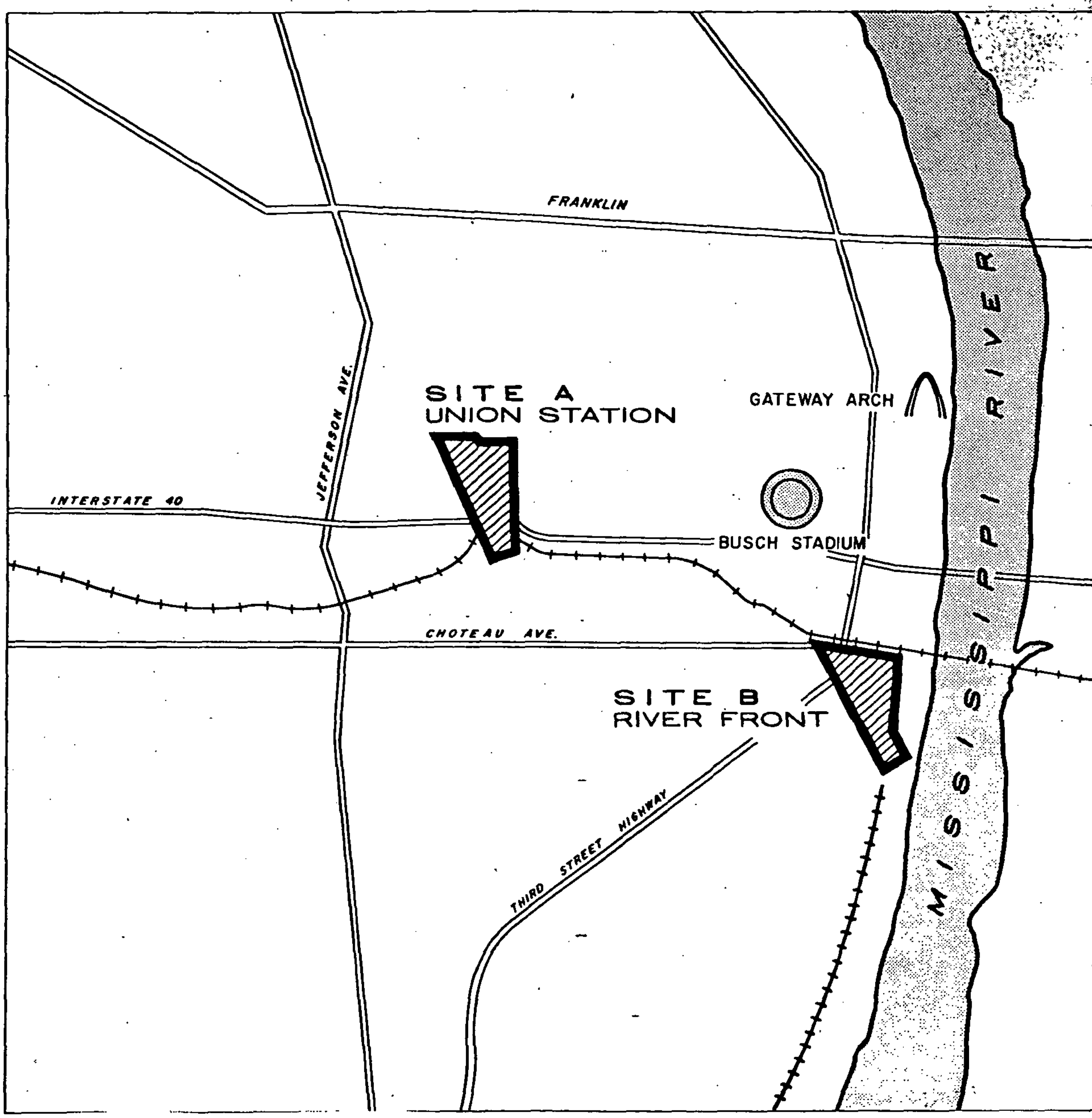


Figure 16

POTENTIAL DOWNTOWN ST. LOUIS STOLPORT SITES

The flow chart developing the simulation model is shown in Figure 17. A skeleton overview of model logic is presented below, followed by detailed discussion of each of the calculation entities in the simulation process. The model makes use of detailed knowledge of various modal arrivals and departures to and from downtown St. Louis related to travel associated with other cities in the midwest. The modes of bus, rail, auto and air are included in the analysis. Arrivals and departures for each mode are developed from a 24 hour distribution for each city.[2] The resultant travel costs, trip lengths, and trip times are computed for all modes over the appropriate origin-destination pairs in the test region.[3] Subsequent to assembling the above travel pattern information, the revenues,total costs, and profits per mode are computed in step 3.0. On the second and all following iterations, STOL is included in the above travel computations, with an associated subsidy level to be tested in the analysis.

Apart from the above, step 4.0 develops the capital cost requirements for bus and rail terminal facilities sited contiguously with the STOL Port location as a transportation center complex. Step 5.0 computes the capital costing requirements for the development of STOL Port facilities, and in step 6.0 various Gross Floor Area options for different contiguous land uses in the transportation center (such as commercial, hotel and light industrial

state and local public agencies, private groups, institutions, and associations, and professionals from a broad range of disciplines.

The elements of the continuing planning process developed through the above interaction are six-fold. They include the following:

1.) Provisions for staged decision points, in a framework of continuous community and technical review and feedback.

2.) A concurrent subregional and regional multi-value focus which exposes both transportation user and impact issues, and insures comprehensive program packages for all alternatives.

3.) A focus on the subregional action level, with a concurrent requirement to determine the interaction between several subregions.

4.) Explicit interaction between the large scale regional plans and specific subregional program packages.

5.) A balanced concern between the distribution of costs and benefits and their aggregate regional value.

6.) A process structured to permit the employment of a range of analytical techniques.

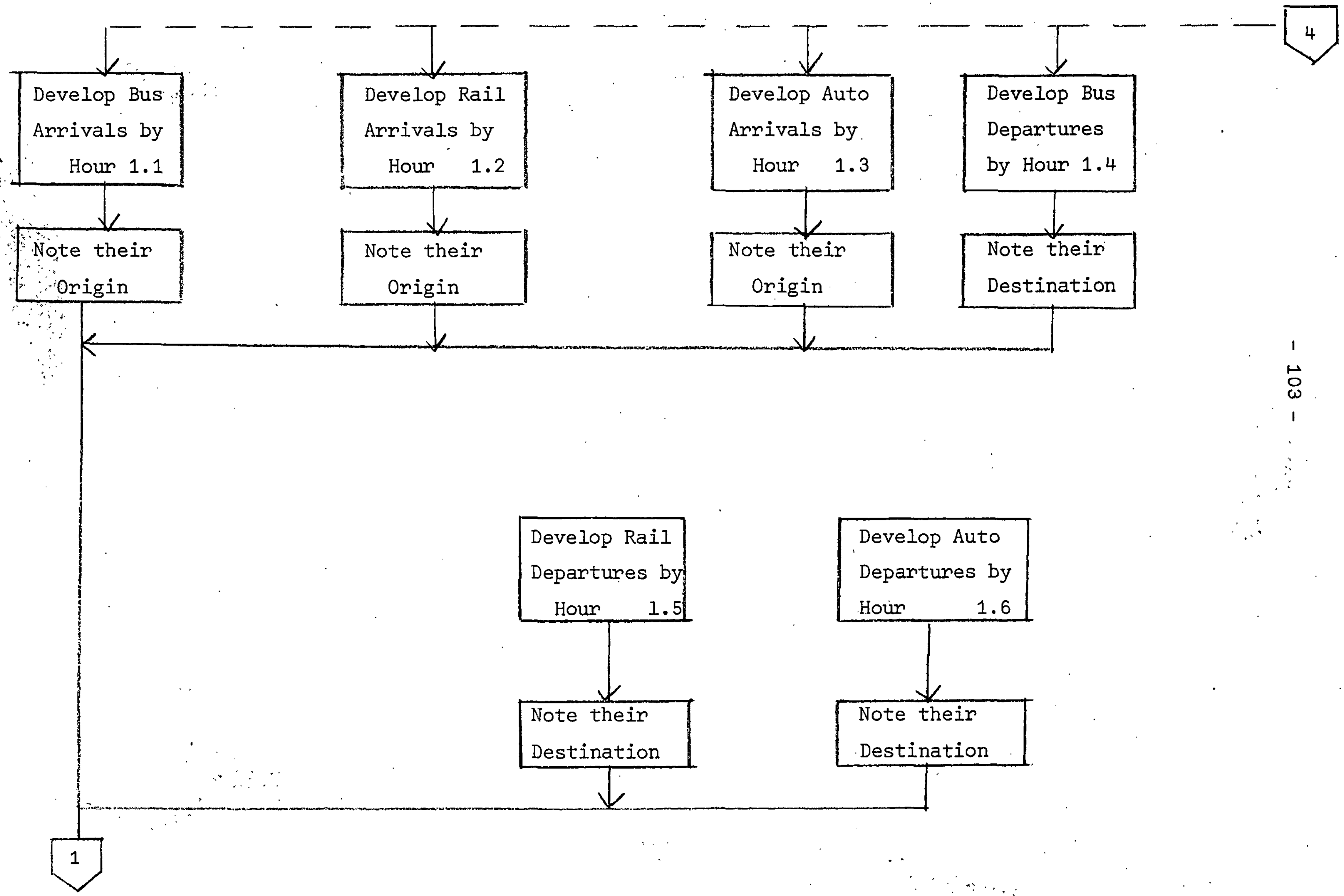
The BTPR used such engineering-economic analysis methods as net benefits, rate of return, total costs vs. total funds available, and benefit-cost ratio. Quantifiable economic and social impacts included measurement of the percent of houses to be relocated, business displacements, relative changes in tax base structure, and pounds of air pollution generated.

facilities) are explored, and their capital cost requirements are computed. Annual rents and charges to be applied to each mode using the transportation center complex in order to recover such capital costs are computed in step 7.0. The associated annual operating costs for the STOL facilities is determined in step 8.0, and an appropriate test STOL flight schedule is developed for all the city pairs in the test region as step 9.

Finally, in step 10, the profitability of the STOL Port is tested against various levels of subsidy of STOL activities. The process continues until the subsidy level reaches the point where the STOL Port facility will financially break-even.

SIMULATION MODEL

Figure 17



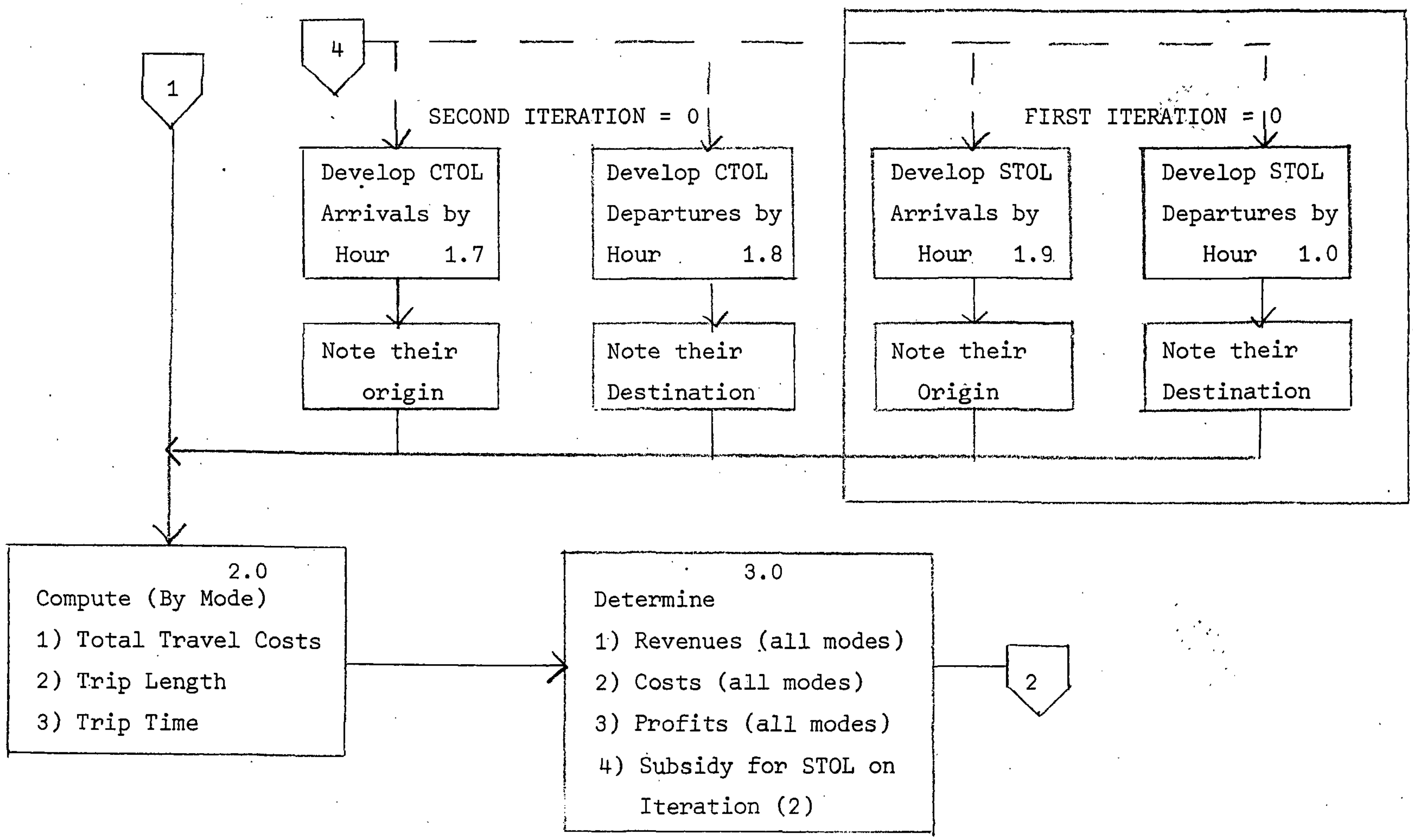


Figure 17 cont.

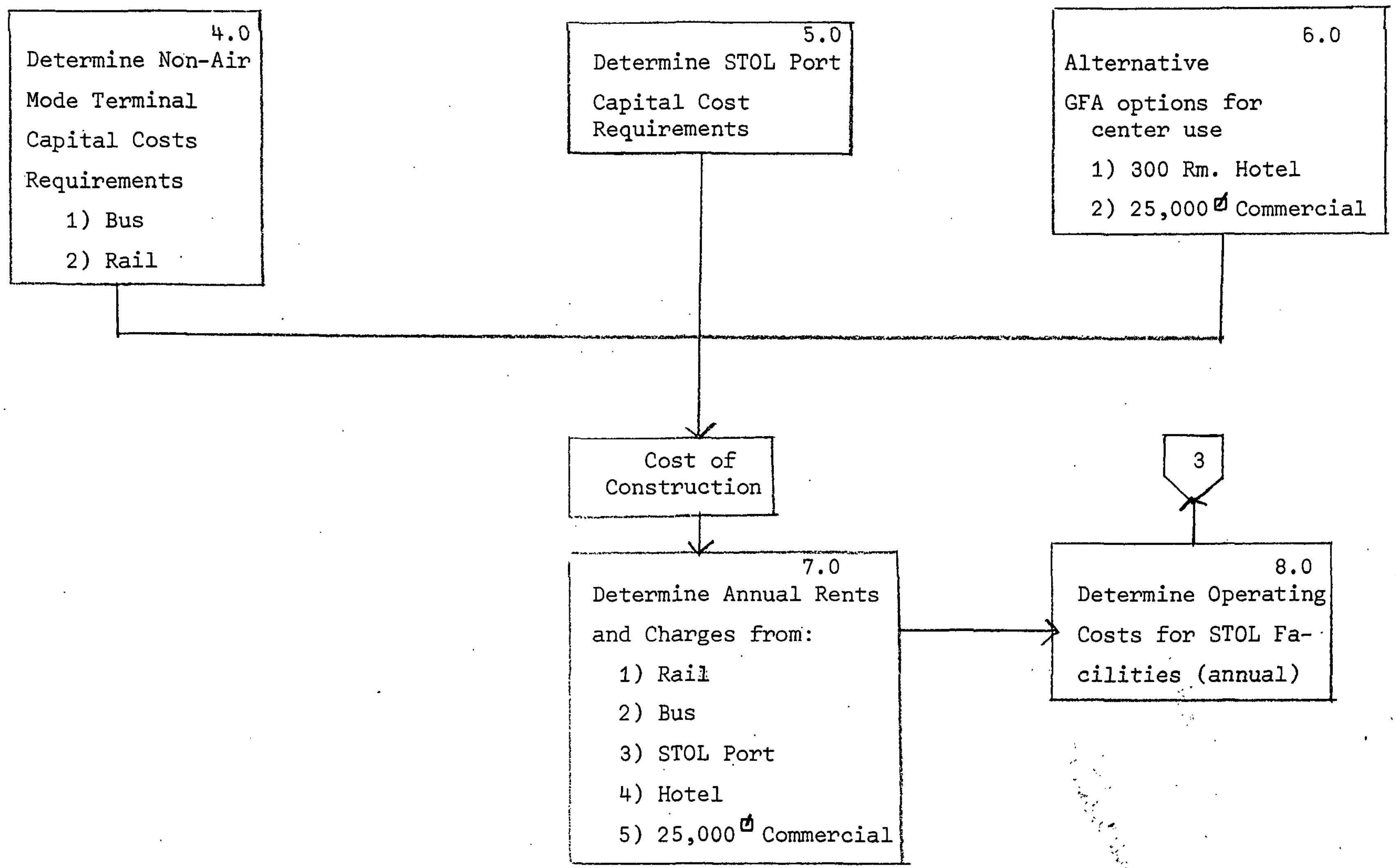


Figure 17 cont.

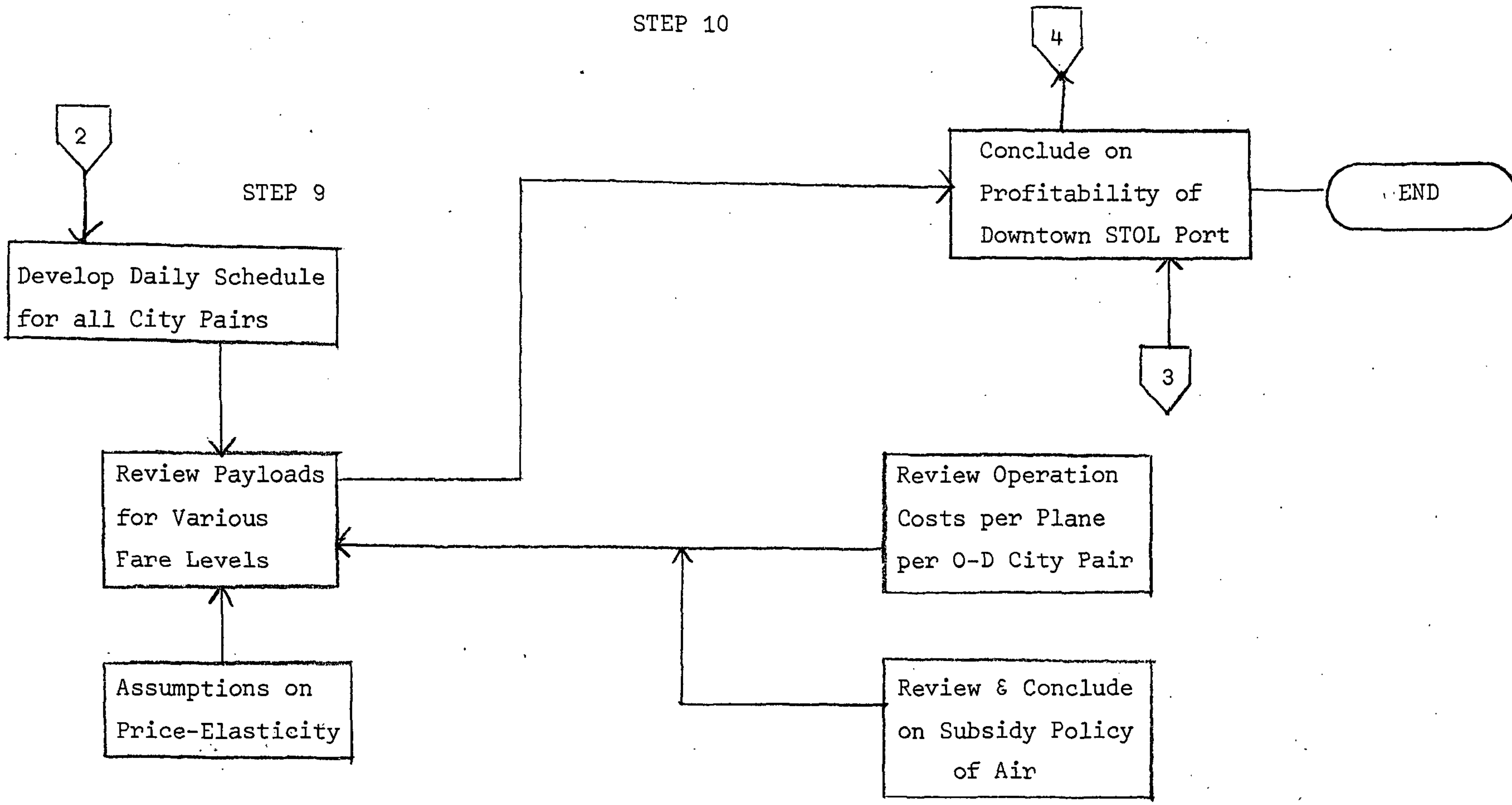


Figure 17 cont.

Travel Behavior Entities

A map of the study area included in the downtown STOL Port analysis appears as Figure 18. It should be noted that cities within a 350 mile radius which functionally relate to St. Louis are typically included in the study design. These cities, and their respective distances from St. Louis are listed in Table 29, together with their annual inbound and outbound air travel volumes.[4] (1)

Obviously, choice of travel mode to a somewhat distant metropolitan center is a function of several variables, and the literature of insights into travel behavior is an endeavor unto itself. However, for the purposes of this analysis, an appropriate surrogate for resulting modal choice is perceived trip cost. The McDonnell-Douglas study of air modal split makes use of this surrogate variable, as noted below:

$$\%\text{Air} = \frac{1}{1+\left(\dfrac{\$\text{AIR}}{K\ \$\text{AUTO}}\right)^{\gamma}}$$

where

% Air = The fraction of total travelers anticipated to travel by air, i.e., air patronage/(total of air and auto patronage)

$AUTO = Total perceived cost of one-way auto trip

Figure 18

MIDWEST STUDY REGION

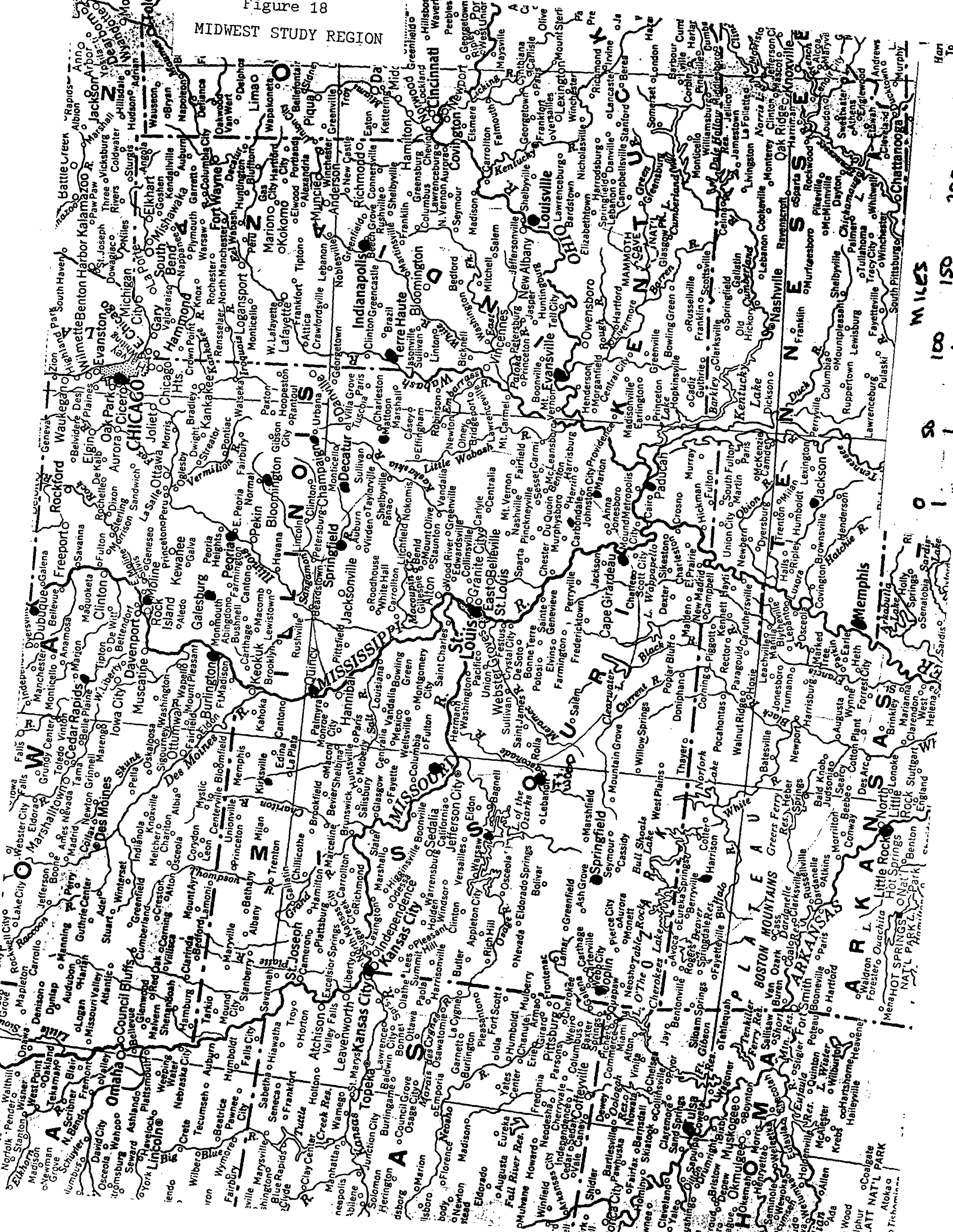


TABLE 29

LIST OF ST. LOUIS CONNECTING CITIES AND THEIR DISTANCE AND AIRLINE PASSENGER CHARACTERISTICS

	CITY NAME	DISTANCE	ANNUAL AIRVOL
1.	Indianapolis, Ind.	229	51210
2.	Chicago, Ill.	256	461120
3.	Kansas City, Mo.	233	138280
4.	Tulsa, Okla.	351	31210
5.	Memphis, Tenn.	255	73230
6.	Evansville, Ind.	161	11300
7.	Little Rock, Ark.	296	38760
8.	Bloomington, Ill.	142	660
9.	Burlington, Iowa	146	3470
10.	Cape Guradeau, Mo.	114	2600
11.	Carbondale, Ill.	90	50
12.	Champaign, Ill.	143	6390
13.	Columbia, J.C., Mo.	99	4430
14.	Decatur, Ill.	109	2640
15.	Dubuque, Iowa	253	1560
16.	Galesburg, Ill.	151	930
17.	Harrison, Ark.	230	1120
18.	Cedar Rapids, Iowa	228	9810
19.	Joplin, Mo.	251	8230
20.	Ft. Leonard Wood, Mo.	119	2580
21.	Kirksville, Mo.	150	470
22.	Lake of the Ozark, Mo.	127	950
23.	Jackson, Tenn.	231	1170
24.	Marion, Ill.	101	2820
25.	Mattoon, Ill.	123	520
26.	Moline, Ill.	190	19250
27.	Peoria, Ill.	137	15310

TABLE 29 cont.

	CITY NAME	DISTANCE	ANNUAL AIRVOL
28.	Louisville, Ky.	254	41500
29.	Quincy, Ill.	94	2690
30.	Madison, Wis.	308	7710
31.	Paducah, Ky.	145	6430
32.	Springfield, Ill.	84	6460
33.	Springfield, Mo.	195	20980
34.	Terre Haute, Ind.	171	770

$AIR = Total perceived cost of one-way air trip

K, γ = Calibration constants

The determination of K and γ was based on the same 1970 data used to project the 1985 total demand. The average traveler value of time was assumed to be $6/hour.[5]

Due to the paucity of intercity modal split analysis of this midwestern region, and the sparse rail service, the above formula was modified for the case study so that bus and rail trips were computed as a component of the % auto. Using current 1975 air volumes in the above formula thus allowed a calibration yielding aggregate trips to St. Louis by bus, rail and auto for each of the cities in Table 29. These trip totals, along with hourly distribution of auto trips is shown for a typical city in Appendix E.

Modal Performance Entities

The particular speed-distance performance relationships and related operational costs and fare determination across all modes is a critical entity set for the analysis. Block speed versus distance for various VTOL, STOL, and CTOL types of operation appears in Figure 19. This graph represents the block speeds at a given distance for various specified cruise speeds associated with CTOL, VTOL or STOL operations. Comparative speed and performance indicators for auto, bus, and rail were synthesized from recent studies involving alternative policies for effecting energy consumption.[6] An example is shown for the St. Louis Intercity corridor in Table 31 below:

Table 31

COMPARATIVE SPEED PERFORMANCE

Mode	Cruise Speed	Block Speed	Block Time
AUTO	55.00	52.15	4.91
BUS	55.00	53.18	4.81
RAIL	94.00	75.67	3.38
CTOL	310.00	245.00	1.04
STOL	270.00	230.00	1.11

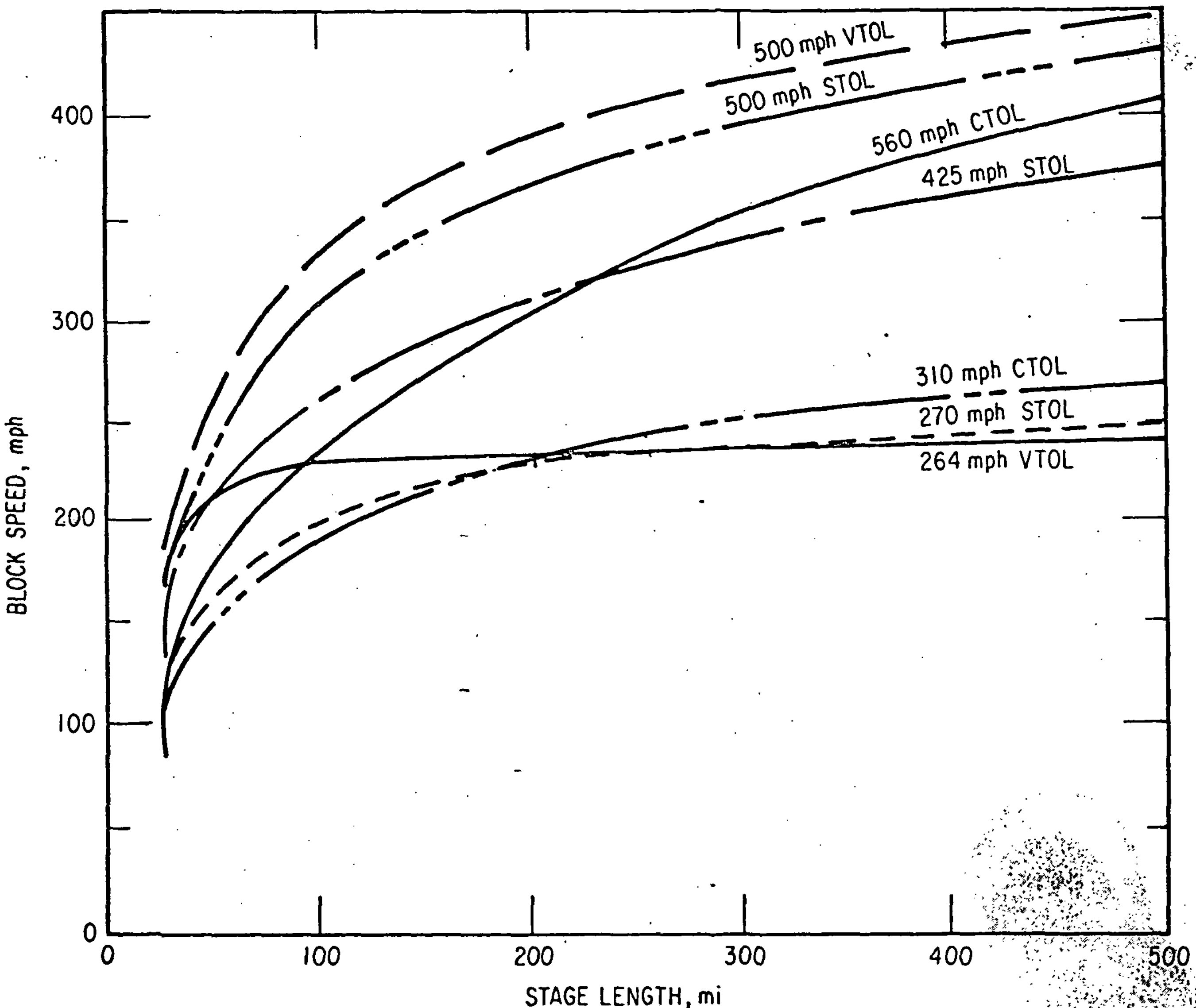


Figure 19 Aircraft Block Speeds Resulting from Combinations of Cruise Speeds and Stage Lengths

Source: Figure 2-2, "Western Region Short Haul Air Transportation Program, Definition Phase Report" Volume II, by the Aerospace Corporation for Western Conference of the Council of State Governments, p.2-5

Fare and cost data was initially developed by employing the actual one-way fares from each city to downtown St. Louis for each mode (BUS, RAIL, CTOL). The Auto cost was calculated using 13¢ a mile (typical allowable auto mileage expense for business purposes) with an average intercity occupancy of 2.5 passengers per trip. The operating cost per passenger mile for bus and rail, shown along with auto at the bottom of Table 32,was based on local interviews which yielded estimates with respect to actual operations within the region.[7] The operating costs for CTOL and STOL, also shown in Table 32,were developed by using 1975 TOC data for CTOL and factoring to yield STOL TOC data, using the same percentage basis for factoring as that developed for documentation of Figure 20.

The fare structure of bus and rail for the cities included in the analysis are those 1975 actual fares by that particular mode, documented for the entire set of cities in Appendix F. The fare for STOL for a particular city was initially assigned the same value as the cost per passenger mile, and subsequently iterated against varying subsidy levels, continually keeping the following formula in equilibrium:

TOC = F + S

where TOC = Total Operating Costs

F = Test fare level

S = Test subsidy structure

TABLE 32

TOTAL OPERATING COSTS

MILES	CTOL (134 passenger) TOC (.55 load factor) per passenger mile	STOL (120 passenger) TOC (.55 load factor) per passenger mile
less than 100	.169	.169
100-150	.159	.164
150-200	.14	.159
200-250	.13	.15
250-350	.1275	.14

Operating Cost Bus = $.05 per passenger mile

Operating Cost Rail = $.0989 per passenger mile

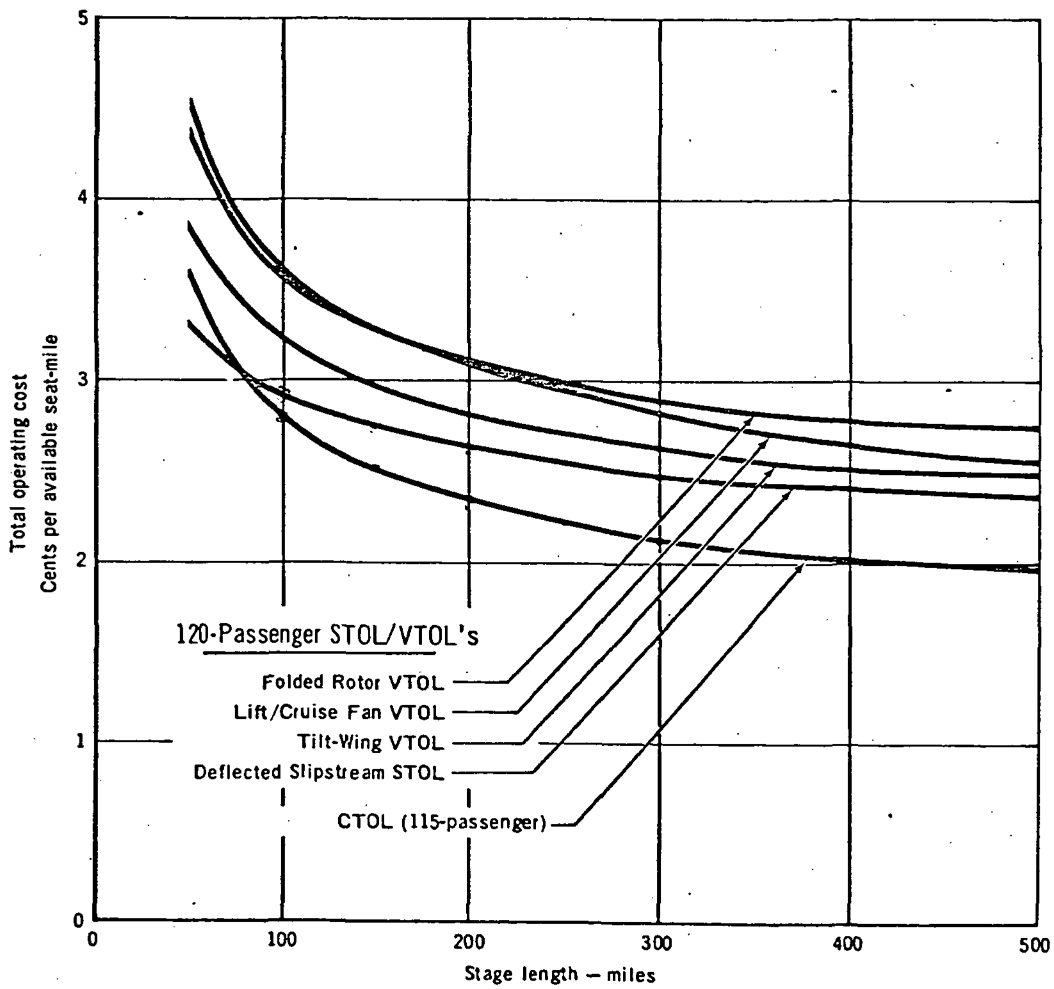


Figure 20 **Total Operating Cost of Study Aircraft (VFR Operation) in 1975.**

Source: Figure 3-15, p. 1-18, Technical and Economic Evaluation of Aircraft for Intercity Short-Haul Transportation, VOL. I, April 1966 McDonnell Aircraft Corporation, for F.A.A. Contract FA65WA - 1246, FAA-ADS-74,1

The rationale for the above iteration, against the mechanics of testing diversion from other modes to the STOL mode through the modal split model are elaborated on in the subsequent sensitivity analysis discussion.

Transportation Center Capital, Acquisition and Maintenance Cost Entities

The cost of facility development and operation are critical in the feasibility analysis. A typical layout of relevant downtown St. Louis five gate STOL Port activities is shown in Figure 21. Comparable unit costs are documented in Table 33. The total capital cost of the center complex is $25,967,216, shown in Table 34. The bulk land acquisition of 33 acres occurs at a market price of $1.50 per square foot.[8] Forty percent of the GFA of the 5 acre bus terminal acreage has light industrial use potentials, yielding construction costs of $25. and $11. per square foot, respectively.[9]

The additional hotel and its associated commercial complex is added to the center as income producing property to anchor the site's financial viability and its staying power as a viable activity center interfacing the modal activity. A 300 room hotel, of the amenity characteristics allowing an average room charge of $30. per night will cost nine million dollars to construct.[10] Its associated 25,000 square feet of commercial has a $25./sq. ft. construction cost. These require 3 acres, with associated acquisition costs of $196,020. The STOL Port construction, requiring 20 acres, and employing unit costs of Table 33 yields an acquisition cost of $1,306,800 and a construction cost of $8,161,000.

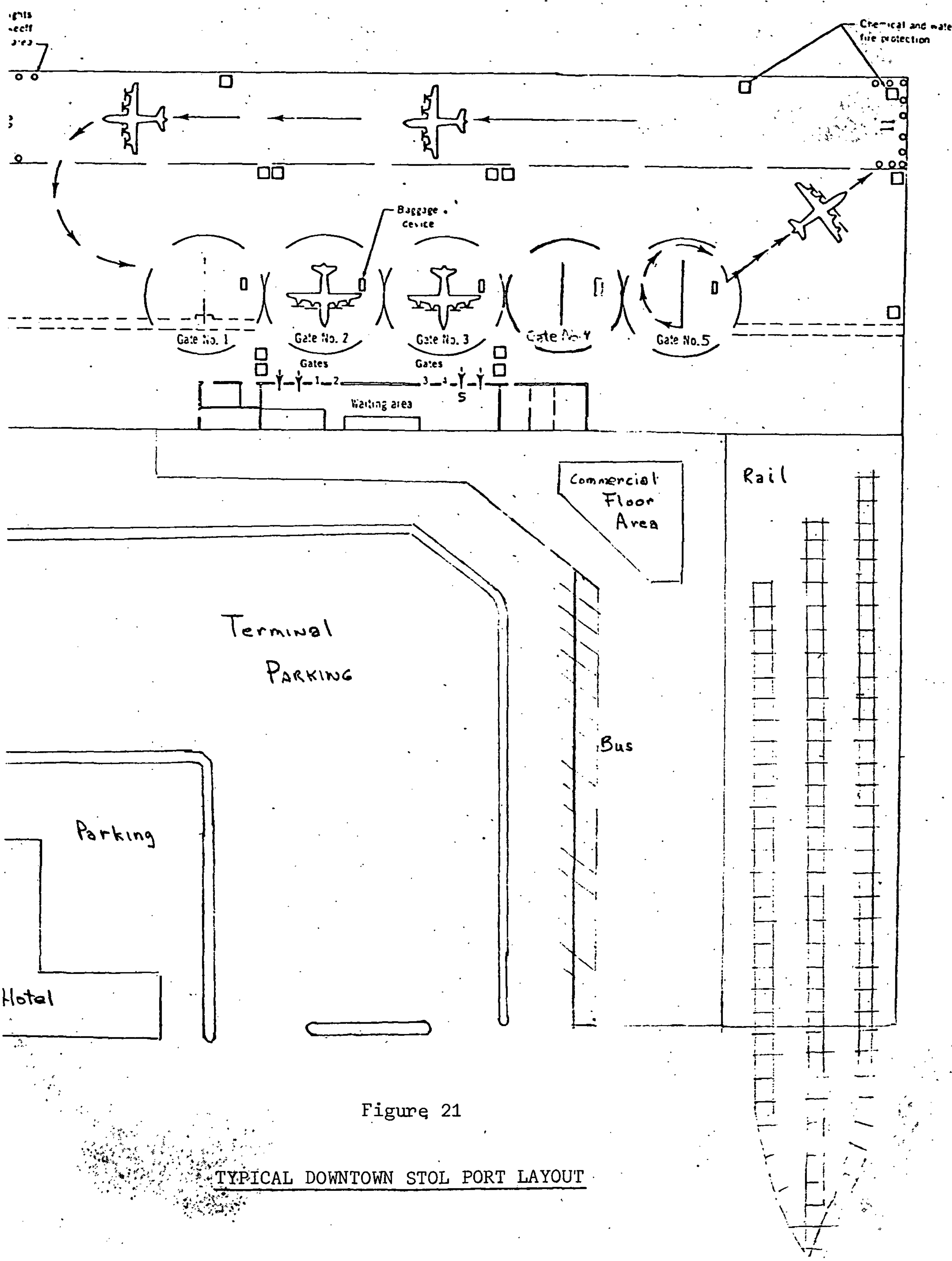


Figure 21

TYPICAL DOWNTOWN STOL PORT LAYOUT

TABLE 33

TYPICAL STOLPORT REQUIREMENTS AND COSTS*

(1)	Runway - 3000 Ft. (914 m) long X 115 Ft. (35 m) wide	$1,150,000
(2)	Taxiway - 6000 Ft. (1829 m) total length X 55 Ft. (17 m) wide	$810,000
(3)	Gates - 5 Gates	$1,675,000
(4)	Terminal ATC Costs	$1,487,000
(5)	Fuel Storage - 400,000 gallons (1,514,000 liters)	$160,000
(6)	Terminals - 84,400 $Ft.^2$ (7841 m^2)	$2,532,000
(7)	Parking Facilities for 1400 cars	$192,000
(8)	Internal Access Road - 4 lanes; 1 mile (1.6 km)	$155,000
	Total	$8,161,000

* Cost does not include real estate, site preparation, demolition, utilities nor external access road costs.

Source: Table 4-18, p. 216, STOL Port Requirements and Costs, Study of Quiet Turbofan STOL Aircraft for Short-Haul Transportation - Final Report, Volume III Airports, June 1973 Douglas Aircraft Company for NASA, Moffett Field, California, NAS2-6994

TABLE 34

CAPITAL COSTS-DOWNTOWN TRANSPORT CENTER

LAND ACQUISITION COSTS		
	STOL Port 20 acres at $1.50 Sq. Ft.	$1,306,800
	Bus & Rail 10 acres at $1.50 Sq. Ft.	$653,400
	Hotel-Commercial 3 acres at $1.50 Sq. Ft.	$196,020
BUILDING COSTS		
	STOL Port	$8,161,000
	Bus & Rail Terminal	$6,000,000
	Hotel 300 Rm.	$9,000,000
	Commercial 25,000 Sq. Ft.	$650,000
TOTAL CAPITAL COST		$25,967,216

TABLE 35

ANNUAL AMOUNT NEEDED TO COVER STOL OPERATING COSTS

		Needed
Maintenance Cost		$460,000
Terminal Costs		$345,000
	Total	$805,000

In addition to the costs detailed above in Table 34, maintenance of the STOL Port terminal and facilities will be important to the STOL Port operator's capital recovery analysis in the immediately following section. Although it is recognized that all land use and terminal entities of Table 34 have maintenance and operating costs, only the STOL Port operation will be detailed here, in order to invoke subsequent capital recovery assumptions in succeeding sections.

Typical annual STOL Port operating costs appear in Table 35 for a five gate STOL Port. The maintenance costs for the air field area are a total of $460,000 and include maintenance and operational activities with respect to:

runways and grounds

fire, crash, rescue and service equipment

air traffic control and landing aids

allocated costs

Likewise, the maintenance and operating expenses for the terminal area amount to $345,000, and include activities related to:

the terminal building (passenger processing area)

parking area

allocated expenses

administrative and general expenses

The total annual maintenance and operating cost thus is $805,000.

Capital Recovery Entity

The required income per facility (or rent) in the Transportation Center appears in Table 36 . These dollar level s represent what each group (hotel, commercial, bus, air, rail) must pay annually to recover the capital cost of the Transportation Center. These conclusions were arrived at by multiplying the capital cost of each facility by a capital recovery factor of .11746 which is a 20 year life without major capital remodelling on renovation, at 10% compound interest. Herein, the analysis involves a critical assumption, that is, each of the above operations (hotel and its associated commercial, bus terminal, rail terminal, and STOL Port) must recover its own capital and operating expenses. That is, no diversion is allowed to occur across operations for one facility to finance deficits of another. This assumption is critical to ensure incentive for private development of hotel and commercial activities, and to separate potential public ownership of STOL facilities and related traffic performance requirements from the rest of the complex. It is presumed that the contiguous "packaging" of rail, bus, hotel and commercial and light industrial activities with STOL into a transportation center will allow economics of scale on mode change and shopping and convention trade to occur such that enhancement of each operator to efficaciously manage his own debt service will be higher than if these facilities were not contiguous .

TABLE 36

ANNUAL AMOUNT NEEDED PER YEAR TO RECOVER CAPITAL COSTS

	Needed
Hotel	$1,115,196
Commercial	$132,828
Bus	$352,380
Rail	$352,380
STOL	$1,663,351
Total	$3,616,135

Thus, for the STOL operator, he must recover the $1,663,351 for capital, and $805,000 for operating costs for a total annual recovery cost of $2,468,351. Money to recover capital and operating costs for the STOL Port will be in the form of landing fees. A relevant landing fee employed for this analysis is $126. per landing for a 120 passenger STOL.[11] Using such as a basis to recover the capital and operating costs as a result of such a transportation center developed herein, at least 63 flights in per day, to the STOL Port, is required as will be examined in the following section on simulation results and related sensitivity analysis.

Simulation Results; Sensitivity Analysis

As stated previously, using a reasonable landing fee, 63 flights into the downtown STOL Port per day will be required to operationally recover capital and operating costs of the STOL Port component of the center. To reach this level of inbound flights will require a subsidy of approximately $.033 per passenger mile to achieve the demand necessary for such a volume, using sensitivity results of iteration of various subsidy and fare computations in conjunction with diversion potential to the air mode from the modal split model.

Such a sensitivity analysis on the demand for various subsidy levels is shown in Table 37, arrayed against the associated number of flights per day and associated annual subsidy. For the volumes and distribution of trips developed herein, such a recovery of capital costs occur with an annual subsidy of $11,000,000.

Table 38 comprehensively demonstrates the volumes of STOL flights for various subsidy levels by city. As a result of increasing the subsidy, the associated required fare drops in the equation TOC= F + S, and the demand for STOL increases such that at a $.04 subsidy per passenger mile the amount of flights by STOL surpases the break-even point for the STOL Port operation of 63 flights.

TABLE 37

SENSITIVITY ANALYSIS ON SUBSIDY REQUIREMENTS

Subsidy	Flights a day (in bound)	Annual Subsidy	Annual Passenger Vols.(STOL) (in bound)
.00	35	0	720,720
.01	41	2,313,480	844,272
.02	48	5,418,192	988,416
.03	58	9,804,600	1,194,336
.04	75	16,628,664	1,544,400

TABLE 38

SCHEDULED STOL FLIGHTS AND RELATED SUBSIDIES

CITY	SUBSIDY PER PASSENGER MILE				
	.00	.01	.02	.03	.04
1	2	2	2	3	4
2	20	23	27	33	41
3	5	6	7	8	11
4	1	1	1	2	2
5	3	3	4	5	6
6					1
7	1	1	2	2	3
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26	1	1	1	1	1
27		1	1	1	1
28	1	2	2	2	3
29					
30					
31					
32					
33	1	1	1	1	2
34					
Total	35	41	48	58	75

(Elements in Table are scheduled inbound flights from cities 1-34; blanks indicate no air service)

Tables 39 and 40 detail the above analysis for a sample city, demonstrating the interaction of the subsidy fare and modal split mechanics. City 3 is 233 miles from the test downtown STOL Port and has a total daily demand of 4286 outbound trips. In Table 39, the daily passenger demand volumes by mode is represented for each of the simulated subsidy levels. Table 40 details this against fare structure in dealing with the diversion to STOL as output from the modal split analysis, and forms a basis for concluding as to critical subsidy level to allow the STOL port operation to financially break even. As can be seen, as subsidy increases from $0.00 to $9.32 per passenger for this particular city, the STOL fare can be reduced from $34.95 to $25.63, allowing a diversion of 356 passenger miles onto STOL from other modes for the trip to the St. Louis downtown STOL Port.

Conclusions

This section has demonstrated an analytically viable way to simulate the packaging of multimodal transportation behavior with likely popular land uses for travelers' activity in the downtown core, allowing ultimate conclusions to be reached on potential financial viability of a downtown STOL Port operation, from the operator's point of view as one of several development actors in the transportation center complex. Two philosophical questions emerge: should the operator be a public

TABLE 39

DAILY PASSENGER VOLUMES RELATED TO SUBSIDY

City 3, distance = 233 miles from downtown St. Louis

	SUBSIDY PER PASSENGER MILE FOR STOL				
Mode	.00	.01	.02	.03	.04
Auto	3699	3647	3578	3483	3342
Bus	141	139	136	132	127
Rail	70	69	68	66	64
STOL	376	428	497	592	732

TABLE 40

FARE - SUBSIDY - RIDERSHIP RELATIONSHIPS FOR CITY 3

For 120 passenger STOL CRAFT .55 load factor	SUBSIDY OF STOL PER PASSENGER MILE .00	.01	.02	.03	.04
Scheduled STOL flights per day	5	6	7	8	11
STOL Fare per passenger	34.95	32.62	30.29	27.96	25.63
STOL Subsidy per passenger	0	2.33	4.66	6.99	9.32
STOL OPERATING COST per passenger	34.95	34.95	34.95	34.95	34.95

works entity? and what are the implications of subsidy, particularly with respect to the equation TOC = F + S. Herein to date, no mention of profit in the TOC entity has been made. These questions as to ownership, profit and subsidy will be dealt with in the conclusions in Chapter VI, along with like questions emanating from succeeding case study analysis sections.

Section B

Peripheral Metropolitan STOL-VTOL Development

The second component of the case study is the investigation methodology for determining the feasibility of STOL or VTOL port location in strategic peripherial locations of the metropolitan region, such that they can potentially serve as effective foci of transportation resources, commuting activity, and land use combinations.

The modelling approach to be used in such feasibility analysis is based on Bayesian Decision Theory, and follows the general format of Figure 22. For a computational treatment of this theory see Appendix B. The advantage of a Bayesian model for analysis of STOL/VTOL development is the degree of flexibility and realism it allows in the evaluation process, as will be demonstrated below.

Relevant combinations of the historical conditions and descriptors of ease of zoning change, national economic status, shifts in regional mobility, and fluidity of land development capital can be incorporated as the"experiments" for the Bayesian analysis. The actual experiment combinations used are noted in Table 41. The associated outcomes of review of the above experimental indicators are prognoses for a successful peripheral development of STOL/VTOL. The

Figure 22

PERIPHERAL STOL/VTOL DEVELOPER'S DILEMMA

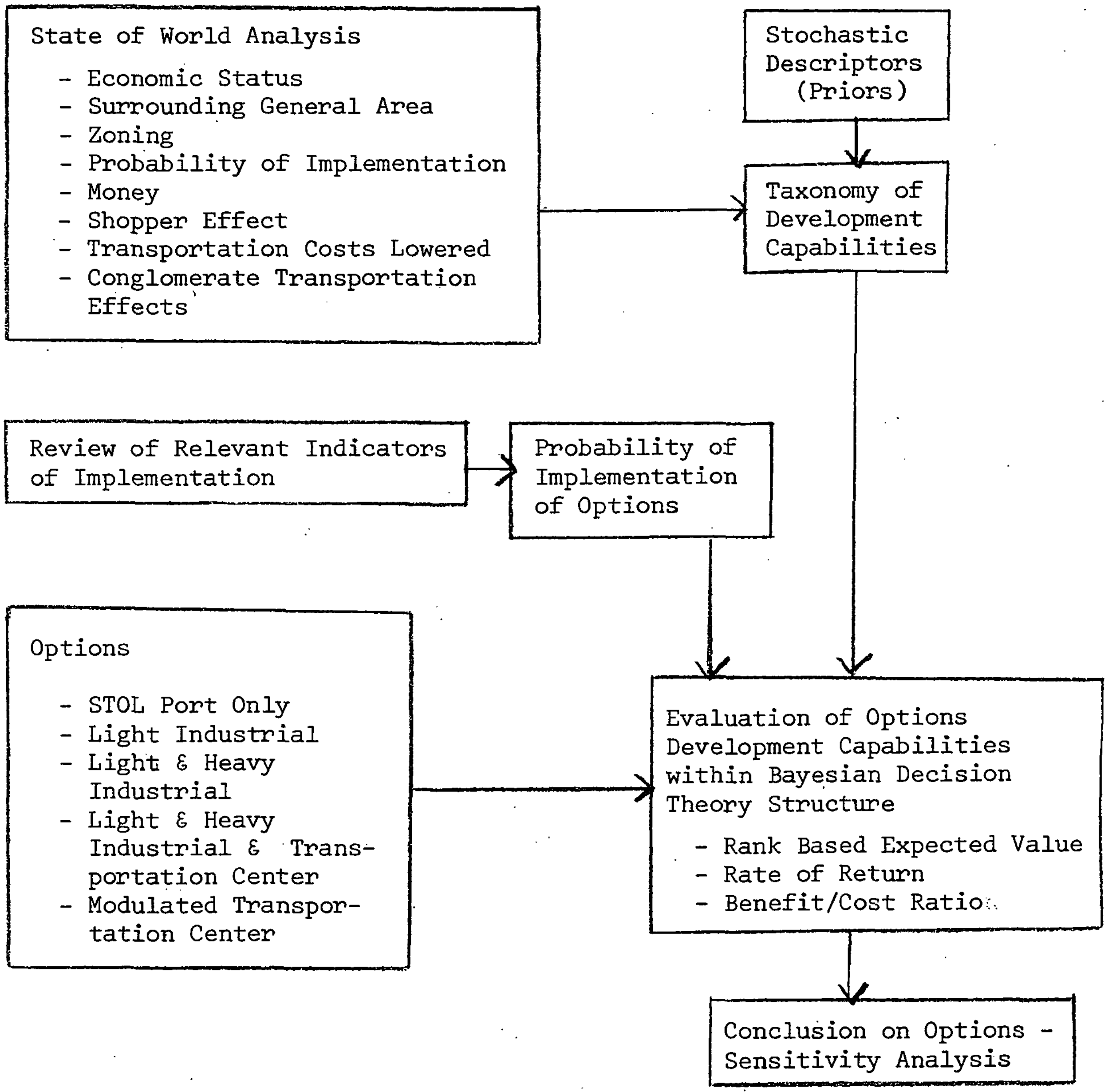


Table 41

BAYESIAN ANALYSIS EXPERIMENT SETS

Experiments Sets and Components

1 - Zoning Change Ability
  - National Economic Status

2 - Zoning Change Ability
  - National Economic Status
  - Mobility Shifts

3 - Zoning Change Ability
  - National Economic Status
  - Fluidity of Land Development Capital

two outcomes used in the analysis are:

1) Development likely to be successful.

2) Development unlikely to be successful.

The action space of the model is shown in Table 42. It consists of five possible development levels varying from siting a STOL/VTOL port only to siting a STOL/VTOL port with associated adjoining private and/or public developments. In addition, the null or do nothing alternative is considered as an action. The state space for the model consists of four descriptions of ultimate conditions for development. An uncertain knowledge exists with respect to which of the four states the potential site will actually be in as the decision analysis is undertaken. The four states relevant to site development are:

1. Conditions are ideal for development.
2. Some aspects are favorable for development.
3. Few aspects are favorable for development.
4. Development is impossible.

To each path through the Bayesian decision tree (i.e. experiment, outcome, action, state) shown in Figure 23 which describes the above problem, a value is attached which represents the utility of a particular combination of experiment, outcome, action and state, $U(e,z,a,\theta)$. These utilities may be arrived at by several different

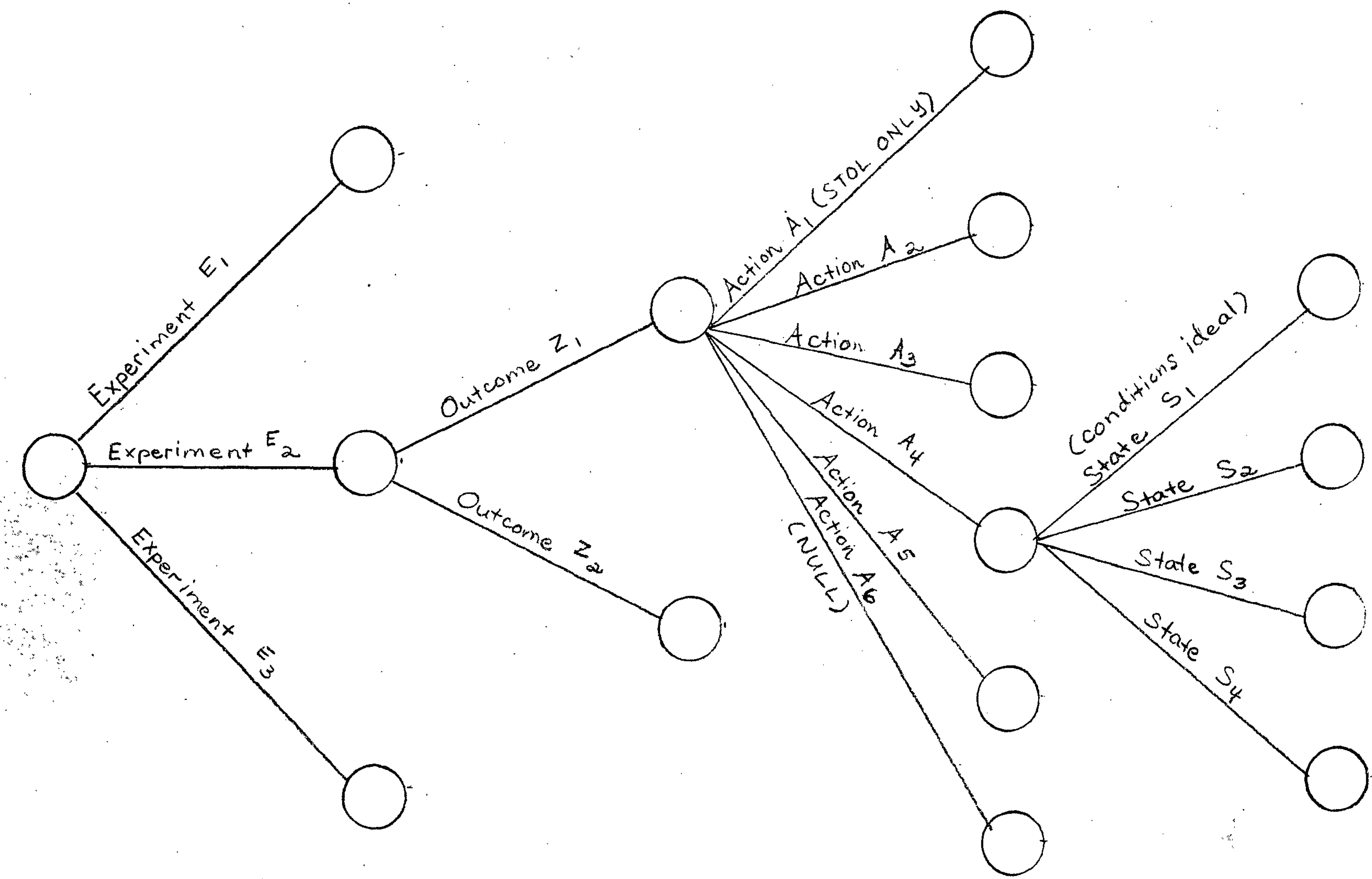


Figure 23

PARTIAL BAYESIAN DECISION TREE FOR PERIPHERAL DEVELOPMENT

means, and within this particular modelling context, utilities were estimated by Internal Rate of Return (ROR) and Rank-based Expected Value (REV) methods. The ROR method was employed where the STOL/VTOL development was considered a private venture. The REV technique was employed where the development was pursued as a public works project, allowing the inclusion of broader, non-monetary impacts in the utility formulation.

To invoke the Bayesian computational format, it is necessary to subjectively estimate two different types of probabilities, the first being the $P'(\theta_i)$ for all i, is the a priori probability of state i occuring. The other set of probabilities estimated are the conditional probabilities $P(Z_J|E_k,\theta_i)$ which are the probabilities of an experimental outcome J, given particular experiment K, and a state with respect to the site. These two subjective estimates of probabilities are developed by making use of the analyst's experience, judgement and interpretation of the experimental historical indicators with respect to site development potential discussed above. The output of the Bayesian analysis indicates the optimal, or critical set of criteria (i.e. the experiment E_k) for evaluating possible development, and the prognosis for development (i.e. the outcome, Z_J), associated with experiment E_K. Based on this particular outcome, the model indicates the optimal site development action to be implemented from those

shown in Table 42. The true state of the site for development is determined as the mechanisms of site implementation unfold, and subsequent to its being in place.

Table 42

POTENTIAL DEVELOPMENT IMPLEMENTATION ACTIONS

Action Sets

1 - STOL/VTOL Only.

2 - STOL/VTOL and Light Industrial Development

3 - STOL/VTOL and Light and Heavy Industrial Development

4 - Transportation Center (STOL/VTOL, RAIL, BUS, Commercial Areas and Hotel)

5 - STOL/VTOL and Light Industrial and Commercial Development

6 - NULL

Case Study Location, Data Inputs, Utility Computational Processes

The actual data inputs are best described in terms of the utility estimating procedures. The ROR method will be dealt with first, followed by the REV method. Appropriate cash flow and utility data are documented in Tables 43 through 48 and will be referred to at appropriate points in the analyses below.

The Rate of Return method requires a series of cash flows for analysis. A potential peripheral location shown in Figure24 in the St. Louis metropolitan area was analyzed for varying action levels of development. Cash flows were constructed based on land costs, capital costs for STOL/VTOL terminals, aircraft costs, travel demand, fares, non-fare income, lease prices for facilities, and capital costs of facilities, etc.

The rank-based expected value analysis requires the capital costs of all facilities, noise impact levels on adjoining land uses, levels of air quality, energy cost, and the Benefit-cost ratio of the STOL/VTOL development. These particular impact categories were chosen as being most typical of the various impacts considered in modern multi-dimensional transportation analysis.

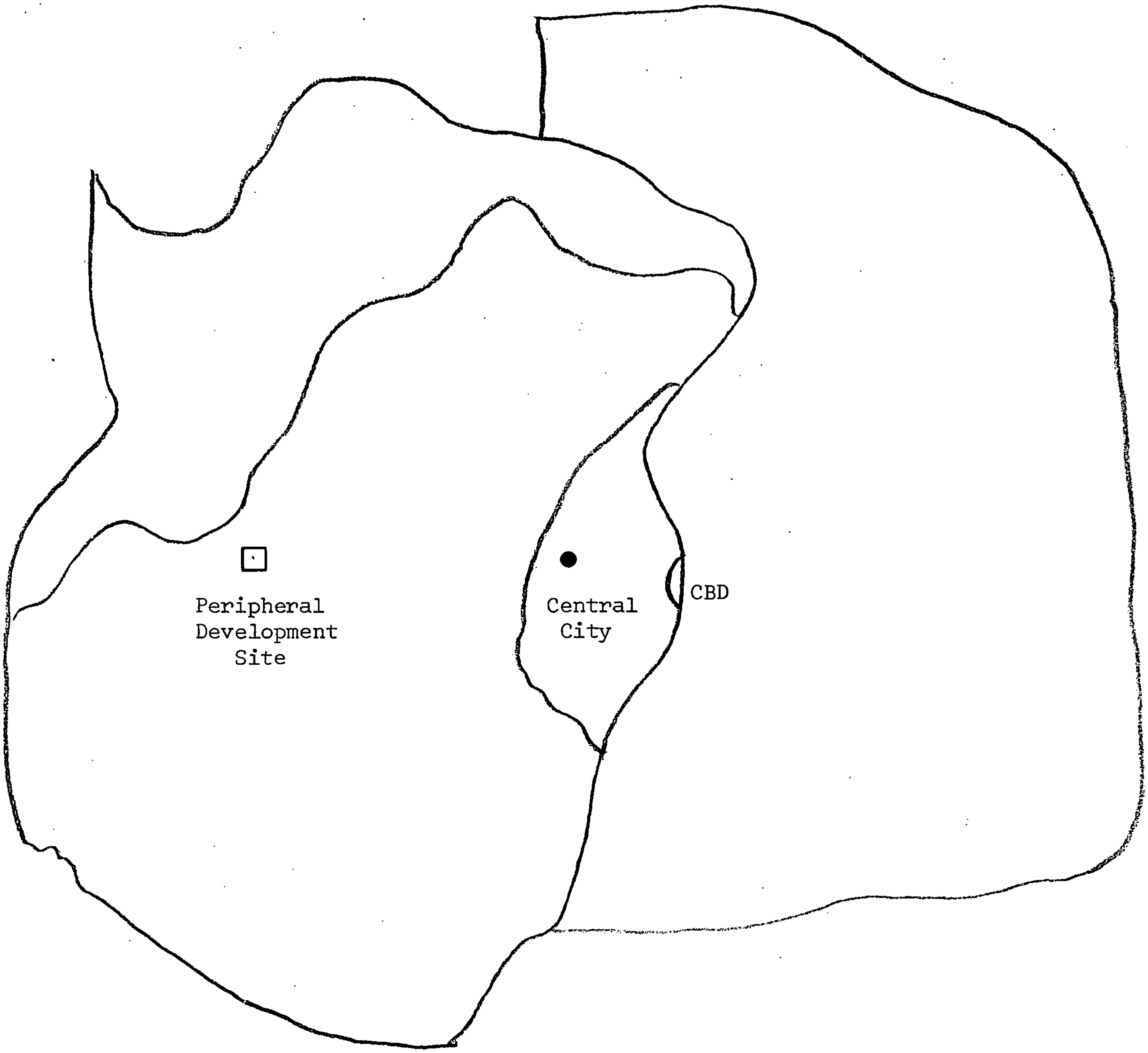


Figure 24

CASE STUDY POTENTIAL PERIPHERAL

STOL/VTOL LOCATION

Rate of Return Analysis

In the ROR analysis, the assumption is made that a private developer would assemble land and facilities and operate with tenants on a long term (20 year) lease basis. It was also assumed that the STOL/VTOL facility would be operated separately from the air carrier serving it.

The STOL/VTOL carrier's rate of return was computed at two unsubsidized fare levels ($5. and $7. per one-way commuting trip of 25 mile distance) and at a demand level of nine hundred passengers per day, which corresponds to the regional potential for two or three peripheral STOL/VTOL facilities serving short intraregional commuting, and jetport feeder service. The assumed site demand levels relate in a consistent manner to the 10,000 passengers per day whose flights either terminate or originate in the St. Louis metropolitan region.[12] A summary of the STOL air carriers incomes, expenditures and rates of return are shown in Table 43 along with the supporting assumptions. The air carrier's rate of return was considered separately from the developer's rate of return. The principal difference between STOL and VTOL carrier operation is the significantly greater capital cost of the air craft.[13] This difference was sufficient in the analysis to eliminate VTOL from consideration at peripheral locations, given the peripheral supply of land to build and

Table 43

RATE OF RETURN CASH FLOWS FOR STOL CARRIER

Configuration

No. Ports 4

No. Planes 3 (60 passenger STOL)

Capital Cost per plane: $ 2M

Daily Passenger Demand 900

No. Flights Daily 15

Aircraft Total operating cost $.045/available seat-mile

Plane Life 10 years

Study period 20 years

FLOW #	YEAR	AMOUNT ($ X 10^3)	
		Fare $7.50	Fare $5.00
1	0	-6000	-6000
2-10	1-9	+1182	+620
11	10	-4818	-5380
12-21	11-20	+1182	+620

Rate of Return ($5.00 Fare) = .60%

Rate of Return ($7.50 Fare) = 14.68%

develop STOL sites.

The rate of return analysis for action 1, STOL port only development, assumes that a private operator leases and operates the STOL facility. His incomes, expenditures and Rate of Return are shown in Table 44. The rate of return is negative given that the developer recovers his capital on improvements at 10% over 20 years. It should be noted that the capital cost is that of a four gate STOL facility, which is based on upgrading of the location shown in Figure 24, an existing peripheral general aviation airport in this region. The alteration to a STOL port will yield facilities as shown in figure 25. The associated $4,127,000 cost[14] is the upgrading cost for runways, taxiways, and terminal, gate and parking facilities. A new facility of equal size would cost approximately twice this amount.[15]

The second alternative, action 2, is a combination STOL/Light industrial facility. The light industrial component would cover approximately 50 acres with 48,400 square feet of building space. Again, it is assumed that the developer leases all facilities to the tenants. The cash flows for this alternative are shown in Table 45. The rate of return for this alternative is very small at 1.03%.

The next alternative, action 3, is the STOL/light industrial/heavy industrial park, where the developer would build and sell the

Table 44

RATE OF RETURN ANALYSIS FOR STOL PORT OPERATOR

No. Ports 4

STOL Port Annual operating cost $500,000

No. Flights per day 15

Landing Fee $100.

Miscellaneous income per passenger $.94 per passenger

Annual lease to developer $485,000

Daily Passengers 900

FLOW	YEAR	AMOUNT ($ X 10^3)
1-20	1-20	-398,500

Rate of Return - negative

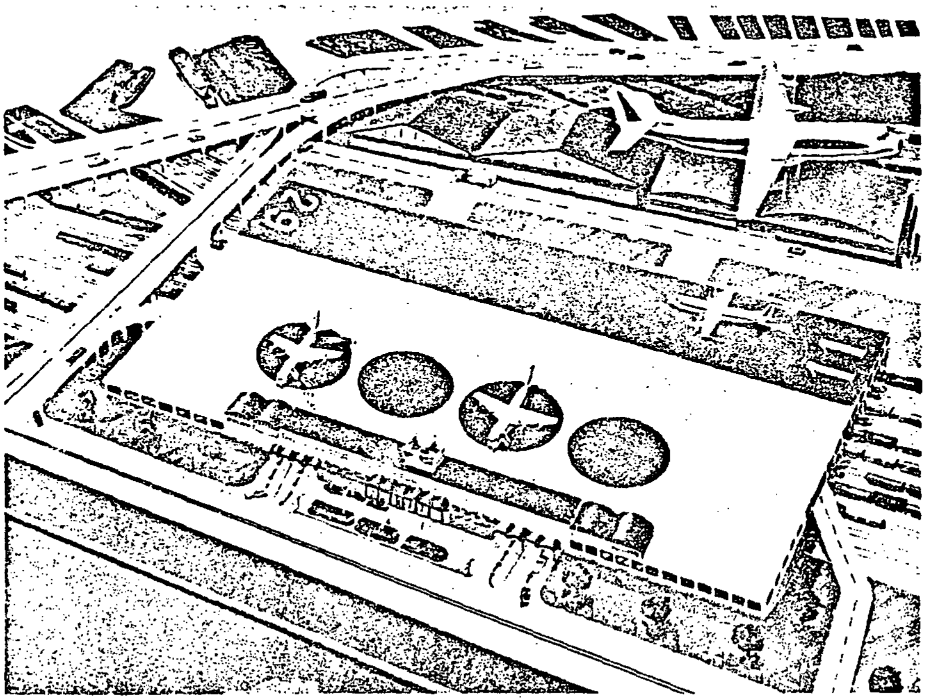


Figure 25

FOUR GATE STOL FACILITY

FOR PERIPHERAL LOCATION

Table 45

RATE OF RETURN ANALYSIS FOR STOL/LI PERIPHERAL DEVELOPMENT

No. Ports 4

No. Acres for STOL 19

No. Acres for Light Industrial 50

No. Square Feet Light Industrial 48,400

Lease Income from Light Industrial (annual) $106,480

Light Industrial Building cost per square foot $11.

Daily Passenger Demand 900

STOL Port total operating costs (annual) $500,000

Flights per day 15

Land price $.40/Square foot

FLOW	YEAR	AMOUNT ($ X 10^3)
1	-2	-1198
2	-1	-4659
3-22	1-20	+262

Rate of Return = 1.03%

heavy industrial component to a client, and lease the light industrial as before. The cash flows are noted in Table 46. The rate of return for this option is significantly improved to approximately 10.1%.

The fourth alternative, action 4, a transportation center, is a composite facility including a STOL/bus/rail terminal with 25,000 square feet of commercial space, and a 300 room hotel. The objective of its operation is to provide a multi-modal interchange facility which serves a large portion of the region. The cash flow summary is shown in Table 47 and the costing assumption is based on a private developer building and then leasing out the components. The rate of return was fairly attractive at 7.91%.

Action 5, consisted of a STOL facility with 48,500 square feet of light industrial building space and 25,000 square feet of commercial space. The cash flows and costing assumptions for this facility are illustrated in Table 48. The rate of return noted was 4.7%. The final alternative, that of no development, was arbitrarily assigned a rate of return of 1% for analysis purposes.

Table 46

RATE OF RETURN ANALYSIS FOR STÓL/LI/HI PERIPHERAL DEVELOPMENT

No. Ports 4

No. Acres for STOL 19

STOL Port operating cost (annual) $500,000

Daily Passenger Demand 900

Land Price per square foot $.40

Light Industrial Acreage 50

Light Industrial Building Square footage 48,400

Light Industrial Building cost per square foot $11.

Heavy Industrial Acreage 50

Heavy Industrial Capital Cost $30 M

FLOW	YEAR	AMOUNT ($ X 10^3)
1	-2	-31,300
2	-1	-4,659
3	0	+37,769
4-23	1-20	+591

Rate of Return = 10.08%

Table 47

RATE OF RETURN ANALYSIS FOR TRANSPORTATION CENTER PERIPHERAL DEVELOPMENT

No. Ports 4

Transportation Center Acreage 25

Capital Costs

Bus, Rail Facility $6M

900 Room Hotel $9M

Commercial Square Footage 25,000

Commercial Lease Income (annual) $125,000

Commercial Building Cost per square foot $25

Miscellaneous Income per passenger $.94

Daily Passenger Demand 900

Land Price per square foot $.40

FLOW	YEAR	AMOUNT ($ X 10^3)
1	-2	-22,550
2-24	1-20	+2,410

Rate of Return = 7.91%

Table 48

Configuration

No. Ports 4

Daily Passenger Demand 900

Light Industrial Acreage 50

Commercial Acreage 25

Light industrial square footage 48,400

Commercial square footage 25,000

Light industrial lease income \$106,480

Commercial lease income \$125,000

STOL port annual operating cost \$500,000

FLOW	YEAR	AMOUNT (\$ X 10^3)
1	-2	-1252
2	-1	-5284
3-22	1-20	+493

Rate of Return = 4.69%

Discussion and Summary

The complete Bayesian input data and output computations for the ROR set and the forthcoming RBEV analysis sets (estimates of $P(Z_j | E_k, S_i)$ and the utilities) is presented in Appendix G. A summary of the sensitivity analysis performed on the a priori probabilities of the different development states occuring is shown in Table 49. The analysis shows that experiment 3 dominates, indicating that zoning change ability, national economic status and fluidity of land development capital are the best criteria for judging feasibility. The indicated optimal action is for a STOL/light industrial/heavy industrial type of development.

Table 49

BAYESIAN ANALYSIS RESULTS WITH RATE OF RETURN UTILITY ESTIMATES

ESTIMATES OF PRIORS ON				OPTIMAL EXPERIMENT	EXPECTED REWARD	OPTIMAL ACTION FOR OUTCOME	
θ_1	θ_2	θ_3	θ_4			Z_1	Z_2
.25	.25	.25	.25	3	8	3	3
.85	.05	.05	.05	3	8	3	3
.05	.85	.05	.05	3	8	3	3
.05	.05	.85	.05	3	8	3	3
.05	.05	.05	.85	1	7	3	3
.1	.1	.4	.4	3	7	3	3
.1	.4	.1	.4	3	7	3	3
.4	.1	.1	.4	3	8	3	3
.4	.1	.4	.1	3	8	3	3

Rank-Based Expected Value Analysis

The alternate set of Bayesian analysis employed is the rank-based expected value technique for estimating utilities for various actions, incorporating public B/C ratio as one of the project's impact utilities. In this analysis, the actions are ranked from least to most desirable with respect to the following five impacts including:

1. The benefit/cost ratio of the STOL facility, reflecting savings in user travel time ratioed against transport facility capital costs.
2. The total energy use by the action.
3. Noise impact.
4. Air quality impact.
5. Capital cost of development.

The modified benefit/cost assumptions for the different actions are shown in Table 49 together with the resulting B/C for each action and its ranking. The null alternative was arbitrarily assigned a B/C of 1. A highly narrow user monetary B/C ratio was developed, with the benefits including only user travel time savings, and costs including only transport facility capital costs. The STOL/Light industrial/heavy industrial and the transportation center, serving the most potential passengers, yielded the highest B/C ratios.

Table 50

IMPACT RANKINGS FOR BENEFIT/COST ANALYSIS

Impact Ranking: Benefit/Cost Analysis

Assumed trip length equivalent to STOL trip: 25 miles

Assumed time savings per trip: 15 minutes

Value of time per hour: \$10.

Capital Cost of STOL Facility: \$4,127,000

Interest Rate: 8%

Project Life: 20 years

Action No.	Rank	B/C	Assumed Daily Demand
6	1. Null Alternative		
1	2. STOL/VTOL Only	1.33	900
2	3. STOL/VTOL and Light Industrial	1.49	1000
5	4. STOL/VTOL, Light Industrial and Commercial	1.64	1100
4	5. STOL/VTOL, Transportation Center	1.71	1150
3	6. STOL/VTOL, Light Industrial and Heavy Industrial	1.78	1200

The energy cost criteria were based on diversion of passengers to more energy efficient modes. These rankings were made subjectively and are depicted in Table 51. The noise impact rankings shown in Table 52 were also subjectively estimated with respect to impacts on adjacent land uses. Air quality rankings were estimated based on an action's potential for indirect source problems, as well as the presence of industrial sources difficulties. These rankings are shown in Table 52. The capital cost of all facilities included in an action are also ranked in Table 52. Two separate analyses of RBEV were performed to test strength of environmental impact concerns on the decision pattern. In the first analysis, the weights were evenly distributed, with noise impact receiving the highest weight. This represents a reasonably balanced regional response to development, with due regard to benefits of public works and development and no overt over-emphasis of enviornmental criteria. As noted in Table 53, the transportation center alternative develops the highest score with this set of weights assumption.

The completed Bayesian analysis for the above utilities is summarized in Table 54. Experiment 3, composed of review of zoning change ability, national economic status, and fluidity of land development capital is dominant. The ultimate optimal action is development

Table 51

IMPACT RANKINGS FOR ENERGY COSTS AND NOISE

Impact Ranking: Energy Cost

Action No.	RANK
6	1. Null Alternative
1	2. STOL/VTOL Only
2	3. STOL/VTOL and Light Industrial
5	4. STOL/VTOL, Light Industrial and Commercial
4	5. STOL/VTOL, Transportation Center
3	6. STOL/VTOL, Light Industrial and Heavy Industrial

Impact Ranking: Noise

Action No.	RANK
6	1. Null Alternative
1	2. STOL/VTOL Only
2	3. STOL/VTOL and Light Industrial
4	4. STOL/VTOL, Transportation Center
5	5. STOL/VTOL, Light Industrial and Commercial
3	6. STOL/VTOL, Light Industrial and Heavy Industrial

(6 = Best)

Table 52

IMPACT RANKINGS FOR AIR QUALITY AND CAPITAL COST

Impact Ranking : Air Quality

Action No.	RANK
3	1. STOL/VTOL, Light Industrial and Heavy Industrial
5	2. STOL/VTOL, Light Industrial and Commercial
6	3. Null Alternative
2	4. STOL/VTOL and Light Industrial
1	5. STOL/VTOL Only
4	6. STOL/VTOL, Transportation Center

Impact Ranking: Capital Cost

Action No.	RANK
3	1. STOL/VTOL, Light Industrial and Heavy Industrial
4	2. STOL /VTOL, Transportation Center
5	3. STOL/VTOL, Light Industrial and Commercial
2	4. STOL/VTOL and Light Industrial
1	5. STOL/VTOL Only
6	6. Null Alternative

(6 = Best)

Table 53

RBEV ANALYSIS

BALANCED REGIONAL RESPONSE

RANK / RESULT

Criteria	Weight	Alternative 1	2	3	4	5	6
B/C	20	2 / 6.7	3 / 10	6 / 20	5 / 16.7	4 / 13.3	1 / 3.3
Energy Cost	20	2 / 6.7	3 / 10	6 / 20	5 / 16.7	4 / 13.3	1 / 3.3
Noise Impact	25	5 / 20.8	4 / 16.7	1 / 4.2	3 / 12.5	2 / 8.3	6 / 25
Air Quality	20	5 / 16.7	4 / 13.3	1 / 3.3	6 / 20	2 / 6.7	3 / 10
Capital Cost	15	5 / 12.5	4 / 10	1 / 2.5	2 / 5	3 / 7.5	6 / 15
	Totals	63.4	60	50	70.9	49.1	56.6

Table 54

BAYESIAN ANALYSIS RESULTS WITH RBEV UTILITY ESTIMATES - BALANCED REGIONAL RESPONSE

ESTIMATES OF PRIORS ON				OPTIMAL EXPERIMENT	EXPECTED REWARD	OPTIMAL ACTION FOR OUTCOME	
θ_1	θ_2	θ_3	θ_4			Z_1	Z_2
.3	.35	.2	.15	3	54	4	4
.4	.3	.15	.15	3	55	4	4
.2	.3	.3	.2	3	53	4	4
.15	.15	.35	.35	3	52	4	4
.05	.05	.45	.45	3	50	4	4
.05	.75	.1	.1	3	53	4	4
.75	.05	.1	.1	3	58	4	4
.05	.05	.8	.1	3	53	4	4
.05	.05	.05	.85	1	49	4	4
.05	.05	.2	.7	1	49	4	4
.05	.05	.3	.6	3	49	4	4

of a transportation center.

The second RBEV analyses used significantly adjusted weights to reflect a heavy regional emphasis on environmental quality, particularly with respect to air and noise impacts. The results of this analysis are shown in Table 55. The STOL only action, and the transportation center alternative have the highest scores, those of 69.1 and 69.9, respectively. The results of the complete Bayesian analysis using these above utility scores are shown in Table 56. Again, the indicators of experiment 3, composed of zoning change ability, national economic status, and fluidity of land development dominate as critical analyses input. The optimal action ultimately indicated is the transportation center.

Table 55

RBEV ANALYSIS

HEAVY REGIONAL EMPHASIS ON ENVIRONMENT

Criteria	Weight	Alternative 1	2	3	4	5	6
B/C	10	2 / 3.3	3 / 5	6 / 10	5 / 8.3	4 / 6.7	1 / 1.7
Energy Cost	10	2 / 3.3	3 / 5	6 / 10	5 / 8.3	4 / 6.7	1 / 1.7
Noise Impact	30	5 / 25	4 / 20	1 / 5	3 / 15	2 / 10	6 / 30
Air Quality	20	5 / 29.2	4 / 23.3	1 / 5.8	6 / 35	2 / 11.7	3 / 17.5
Capital Cost	15	5 / 8.3	4 / 6.7	1 / 1.7	2 / 3.3	3 / 5	6 / 10
	Totals	69.1	60	32.5	69.9	40.1	60.9

Table 56

BAYESIAN ANALYSIS RESULTS WITH RBEV UTILITY ESTIMATES - HEAVY REGIONAL EMPHASIS ON ENVIRONMENT

ESTIMATES OF PRIORS ON				OPTIMAL EXPERIMENT	EXPECTED REWARD	OPTIMAL ACTION FOR OUTCOME	
θ_1	θ_2	θ_3	θ_4			Z_1	Z_2
.25	.25	.25	.25	3	52	4	4
.85	.05	.05	.05	3	58	4	4
.05	.85	.05	.05	3	52	4	4
.05	.05	.85	.05	3	52	4	4
.05	.05	.05	.85	1	49	4	4
.4	.4	.1	.1	3	55	4	4
.4	.1	.4	.1	3	55	4	4
.4	.1	.1	.4	3	52	4	4
.1	.4	.4	.1	3	52	4	4
.1	.4	.1	.4	3	50	4	4

Comparison of Results

A comparison of the Bayesian results for the ROR estimates, and for the two RBEV estimates indicates some reasonable conclusions. The rate of return method favors a STOL/light industrial/ heavy industrial development with its reasonable risk and high monetary return, while the RBEV method, incorporating environmental and public welfare components, favors the transportation center, which yields a public transportation center, without concomitant industrial environmental impacts which are viewed in a negative manner by the region. Obviously, the relative strength of this negative assessment of impacts may be captured and tested for its dominance in the decision process through a sensitivity analysis on the weights, $P'(\Theta_i)$ and $P(Z_J | E_k, \Theta i)$.

This discussion concludes the development and testing of a feasibility modelling approach for integrating STOL/VTOL development into the peripheral land uses of a region. The approach structures the location and feasibility problem, and defines the types of inputs necessary for a decision. In subsequent sections, discussion of its linkage to other comprehensive regional evaluation techniques will occur, demonstrating this component's position in formulating a sound comprehensive policy analysis system for STOL/VTOL feasibility.

SECTION C

SOCIO-POLITICAL ANALYSIS

This section of the case study pertains to development of the modeling framework which allows improved understanding of the potential for public acceptance and implementation of a major public works project, such as a STOL/VTOL facility. Although applicable in any context of the unfolding case study evaluation strategy, it will be discussed with specific reference to the preceding peripheral development issue, due to common threads of environmental and citizen concerns which are attached to the peripheral location problem and the dynamics that can be specifically articulated in this section.

The underlying concept of this modeling strategy is to analyze a specific public works investment, such as STOL/VTOL development actions at a peripheral site,with respect to the response of interest groups affected by its presence or implementation. The modelling framework attempts to perceive and understand the real environment through a synthetic modelling system. This system can be represented as a function of conditions, behavior patterns, and interaction mechanisms simulating the real patterns of response and interaction of citizen groups pressuring for their point of view with respect to the project's implementation alternatives.

Such citizen group responses can be structurally modelled as competitive decision models, more popularly termed "game theory." A complete discussion of types of game theory processes relevant to this research is covered in Volume I, pp. 50-55.[16] These approaches are conceptually relevant attempts to capture the structure of citizen values and conflict in the struggle between subgroups to promote the alteration of facility locations and designs when they are affected adversely by them. A modified structure of an n-person, open sum game construct is developed herein for its underlying logic fit in the case study STOL/VTOL peripheral location process, and its insight in structuring affected group and community strategies.

In such context, each group assesses several location and/or development alternatives, and pressures for acceptance of them to a greater or lesser extent, depending on their value structure, and pressure being exerted for each of the alternatives by the other groups of the community. Conceptual solutions, as will be demonstrated later, yield a relative measure of pressure or support each group involved in the location-development process should attach to each alternative to minimize the loss, in light of similar maneuvering of emphasis by other groups. In the current planning process, such offering of support or pressure occurs through the public hearing process, appropriate planning or public works commission meetings, or an informal articulation of the group's point of view to

responsible professional and public officials.

Conceptual Delineation of Actor Groups

The first aspect of the modeling system is the actor delineation pertinent to the specific case study public works project. The most obvious group is composed of the residents and land users adjacent to the proposed peripheral siting and STOL/VTOL development options. This group will bear the brunt of any negative impacts, such as noise, air pollution, and related changes in property values. An examination of the resident's socio-economic characteristics will yield a preliminary indication of the group's preferences, and the likely response to the project alternatives they will articulate. The second actor group is composed of area residents and land users which are in the same general geographic jurisdiction, but not immediately adjacent to the site options. Typically, these are residents and land users within the same school district, township, or city and are often buffered from the most immediate adverse project effects, but derive the project benefits of increased mobility, employment opportunities and added tax base.

Another particularly significant set of actor groups is the possible voluntary organizations which may be standing at large, or

previously formed and ready to respond to specific issues such as wildlife and environmental groups, and commerce and growth associations. These organizations are essentially citizen lobby groups and can bring substantial pressure on local and regional political actors, thus influencing the decision making structure of the community. In all succeeding discussions and analysis, reference to local land users and land users in the same jurisdiction includes the environmental groups who may come to their aid. Likewise, commerce and growth lobbies are included in the group subsequently referenced as financial institutions.

A large geographic actor group to be considered is the general St. Louis County population. In addition to countywide socio-economic characteristics, regional development patterns are an important indicator of public support. Patterns of activity center location, building density, and transportation orientation are indicative of the consensus of development perspectives.

The project developers constitute a very specific actor group to be considered. Their involvement pertaining to a specific site is dependent on their perception of the development options open to them, the potential for project implementation, and signals of community support. These are conceptually and conputationally developed in detail in the previous section on peripheral STOL location and development feasibility.

Two other actor groups are both political in nature. One such group is the local government, whose jurisdiction relates to the near and adjoining residents. The elected political decision-makers have general guidelines with respect to effectiveness of community operation, budget constraints, tax base and functions of municipal government which would be enhanced by the development options. However, the elected political leadership is greatly influenced by resident reaction through voter strength. A conflict between enhancement of city effectiveness due to the presence of development and pleasing voter reaction may arise if the city has jurisdiction over a potential zoning change which may emanate from the development effort. Another political actor group is the county or regional governmental structure. This group is more concerned with an aggregate attractive and balanced land development appeal than with isolated voter appeal. This group may also impose substantive criteria with respect to the alternatives,in light of the current long range county or metropolitan land use plan and growth guidelines, and the prospective zoning changes.

The final actor group to be considered is the set of financial institutions capable of investing in the private aspects of the development. Their activity in the implementation scheme is crucial for the project's feasibility. The project in question will be viewed by them as being in competition for funds with other investment

opportunities,in terms of implementation feasibility, return on investment, and local and national development perspectives.

Each of these above actor groups is affected by the impacts of the proposed development in a different manner, depending on their objectives and values. An analytically composite list of impacts relevant to the development, and those connected with the previous peripheral STOL development analysis includes capital cost, noise, air quality, regional value added, total personal income, and energy cost. A ranking of impact importance by actor groups in the St. Louis case study is presented in Table 57. As can be seen, priorities of concern range from noise and air quality for adjacent residents,to regional value added (a surrogate for return on investment) for financial institutions and developers.

If all actor groups functioned in strictly individual ways, with no knowledge of each others perceptions and implementation priorities, the project might be impossible to acheive. However, typically actors whose perceived values are similar, will coalesce in order to further their chances for successful project implementation or rejection. A schematic representation of this interactive sequence is presented in Figure 26. Based on the magnitudes of these interactions, certain groups align themselves behind a particular development concept. In light of such coalescence, a

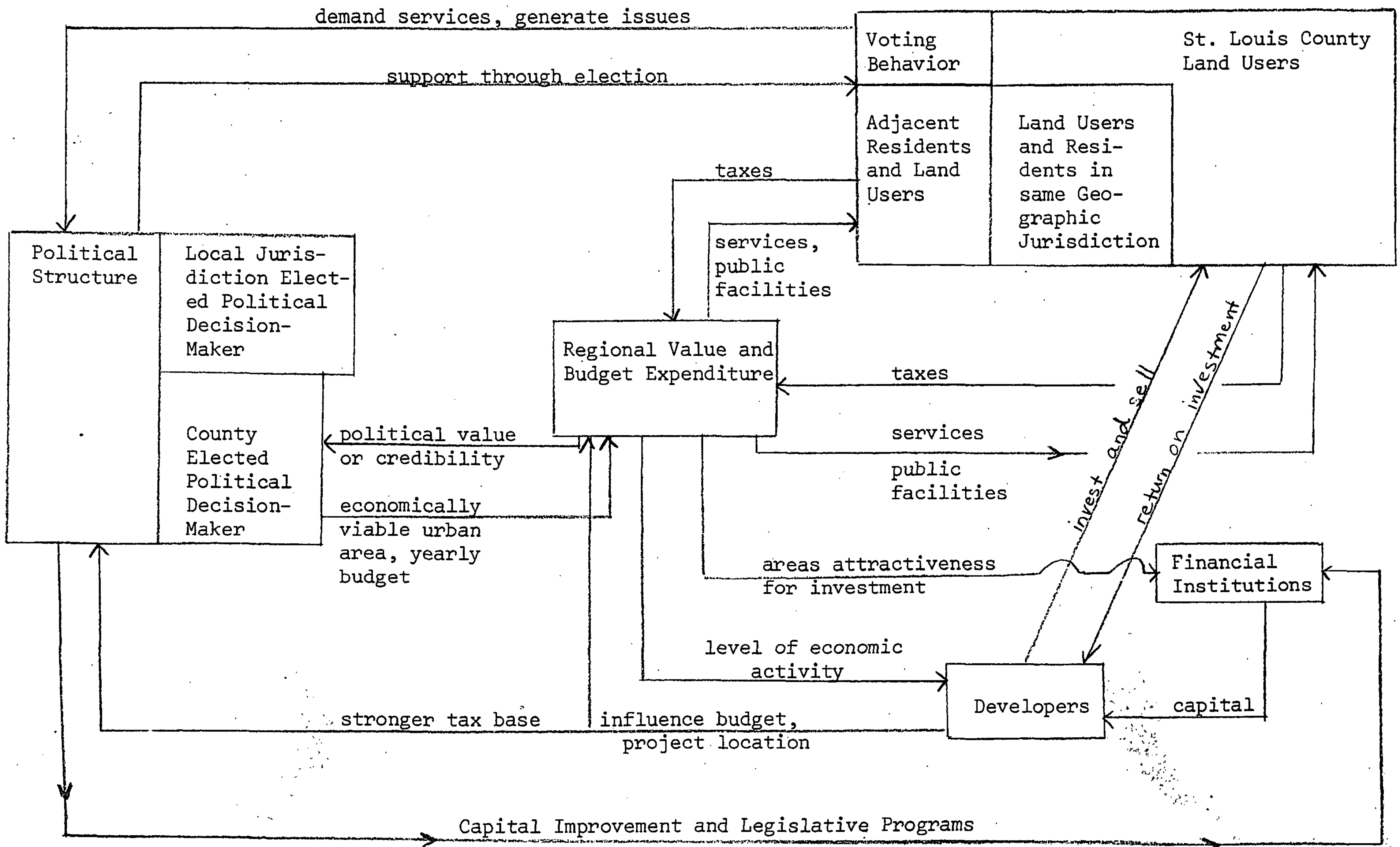
Table 57

RANKING OF IMPACT IMPORTANCE BY ACTOR GROUPS

Impacts of Development	RANKING						
	Adjacent Residents and Land Users	Land Users and Residents in same Geographic Jurisdiction	St. Louis County Land Users	Developers	Local Jurisdiction Elected Political Decision-Maker	County Elected Political Decision-Maker	Financial Institutions
1. Capital Cost	5	5	2	2	1	2	3
2. Noise	1	1	4	5	2	5	5
3. Pollution	2	2	5	6	3	4	6
4. Regional Value Added	6	4	3	1	6	1	1
5. Total Personal Income	3	3	1	3	5	3	2
6. Energy Cost	4	6	6	4	4	6	4

Figure 26

ACTOR GROUP INTERACTION



most significant set of actor groups are appropriate governmental levels of a regulatory nature, i.e., the city, county and/or regional government units which have the final decision with respect to the typical implementation mechanics of zoning changes, permit issuance, etc.(barring judicial intervention through injunctions or civil suits). Further, in the dynamics of coalescence in an n-person game theoretic sense,each individual actor's strategy is sensitive to changes through plan modification, education, or rewards. However, the immediate decision of each actor is less sensitive to modification if he perceives he has a great deal to lose by altering his original strategy or viewpoint.

Schematic Use of the Above in the Peripheral Location Analysis

Implementation components of the case study peripheral analysis can be analyzed with respect to appropriate actor groups in the St. Louis metropolitan area. A representative peripheral location alternative space might consist of:

a_1 STOL port only

a_2 STOL port + Light Industrial Park

a_3 STOL port + Light Industrial + Heavy Industrial Facilities

a_4 STOL port - Transportation Center with Commercial hotel activities

a_5 Null alternative - do nothing

Further, the analysis formulated a state space of:

S_1 Conditions Ideal for Development

S_2 Some Aspects favorable for Development

S_3 Few Aspects Favorable for Development

S_4 Development impossible

Based on interviews with zoning lawyers, real estate appraisers, developers, financial institution officers, and review of recent non-residential zoning cases on the St. Louis metropolitan periphery, a predicted initial response of each of the actor groups with respect to alternatives a_1,-----,a_5 was developed.[17] This is portrayed in Table 58, wherein the elements of the table are probabilities which represent the relative support each actor group will give to each alternative if called to respond competitively to another actor group's point of view, e.g., in activities of placing statements of record in a zoning or project public hearing, or in pre-hearing defense of individual viewpoints to a select audience of professional analysts and/or political decision makers. The probabilities are informative, in that they offer initial monitoring of the actor group's sensitivity to specific project alternatives. These probabilities, as stated above, may be changed through educa-

Table 58

ACTOR GROUP INDIVIDUAL RELATIVE SUPPORT OF ALTERNATIVES

St. Louis Area Actor Groups	STOL port only a_1	STOL port + Light Industrial Park a_2	STOL port + Light Industrial + Heavy Industrial Facilities a_3	STOL port-Transportation Center with Commercial & Hotel Activities a_4	Null-Do Nothing a_5
Adjacent Residents & Land Users	.10	.5	0.0	.15	.70
Land Users & Residents in same Geographic Jurisdiction	.20	.10	.5	.15	.50
St. Louis County Land Users	.15	.15	.15	.15	.40
Developer	.10	.20	.60	.10	0.0
Local Jurisdiction Elected Political Decision-Makers	.10	.15	.10	.15	.50
St. Louis County Elected Political Decision-Makers	.5	.15	.25	.15	.40
Financial Institutions	.10	.15	.25	.30	.20

tion, alteration of plan alternatives to those more appealing to a particular viewpoint, or through reward or compensation to a group which perceives itself disenfranchised in the decision process. The probabilities are useful, not for their precise quantitative value, but as forms of the $P'(\Theta_i)$ in the previous section. That is, a cursory review of them over all possible groups and development actions yields a subjective, but orderly information basis from which to forecast general success of development based on local and regional decision makers interaction, and to initialize the $P'(\Theta_i)$ simultaneous to reviewing historical and economic conditions with respect to formulating the $P(Z_J | E_k, \Theta_i)$.

Coalescence- Emergence of Decision Patterns

The above process is simplified as coalescence of actor groups emerges, yielding fewer proponent groups, and revised responses to more crystallized alternatives. As can be concluded from Table 58, the adjacent land users and those in the same area have relatively high preference for no development. At the other extreme, the developer and financial institutions support development which offers an attractive rate of return. As per the analysis in the preceding section, the developer perceives maximum rate of return on a_3, combining leasing and sales activity of commercial and industrial land uses. The financial institutions' response reflects their desire to

spread their risk, and look carefully at all private options prior to decisions for placement of resources. The county land users'response,reflects an aggregate indifference to the project, while St. Louis County political decision-makers attempt to balance their response yet revealing a desire for development with high rate of return (a_3 the light-heavy industry combination) for the county and metropolitan area economic health. The local jurisdiction has developed an extremely balanced response, revealing its desire to react to citizen pressure in the decision.

As such, it is possible to predict the coalescence of those groups having like rankings on the impacts of Table 57, and similar levels of relative support for specific projects, and to also identify those groups who are initially neutral. The predicted set of coalesced actor groups in the St. Louis area is shown in Figure 27.

It is at this point in the decision process that predictable shifts of support may occur, due to education, modification of alternatives and/or compensation. A demonstration of this yields the predicted alternate choice of a_4, as a development which may have the concensus of groups for its implementation (the STOL + Transportation Center + Commercial/Hotel Complex arrived at through the RBEV technique in the previous section).

Figure 27

EMERGING COALESCED GROUPS IN CASE STUDY PERIPHERAL LOCATION DECISIONS PATTERNS

a_5

Do Nothing:

Coalesced group 1
- Adjacent land owners
- Land owners in same geographic jurisdiction

a_3

STOL Port + Light Industry + Heavy Industry:

Coalesced group 2
- Developers
- Financial Institutions

Uncommitted:

Coalesced group 3
- St. Louis County Land Users
- Local Jurisdiction Elected Political Decision-Makers
- St. Louis County Elected Political Decision-Makers

The groups in Figure 27 represent the final framework for conflict and stand-off, or compromise. Major development with excessive environmental impact will be vetoed by group 1. The developer and financial institutions through their legal resources and commerce lobby will pressure for a development, but one which is sound from a risk perspective with respect to the financial institutions' risk-aversion viewpoint. The uncommitted group 3 composed of government and political groups, and the citizens at large desire opportunity for development, but not with excessive environmental degradation, or at the expense of voter appeal.

As these viewpoints are reviewed across all groups through appropriate professional briefing and interaction, it is predicted that a compromise will be developed which allows development to occur that is as innocuous as possible to the residents of the area, and rewards them for their inconvenience through lowered tax base due to presence of development, and entities of the development which have a valid and currently nonexistent amenity level in the community. Further, such a compromise should be beneficial to the county at large, and innocuous to the political decision-makers' concerns.

In light of the above exhaustive compromise criteria, the extreme alternatives of do nothing vs. presence of heavy industrial

will be rejected and a_4, the transportation center + commercial/ hotel complex will be fostered as an alternative with predicted potential success for implementation and associated zoning changes and permit issuances. The development risk fits the financial institutions' requirements, and its opportunities nominally fit the developers objectives. The education of the local and surrounding residents with respect to the recognizable rewards of lowered tax base, and the advantages of improved shopping and entertainment accessibility, and the opportunity for improved multimodal regional commuting and travel options, has a reasonable chance of shifting their relative support to a level of acceptance that yields implementation. The local and county political decision-makers and citizens at large are able to foresee a project implementation which improves their economic health, without severe adverse political reactions. Thus, the ultimate predicted Pareto Optimal project is a_4, based on intensive review of actor groups, and dialogue across them by the professional and planner-engineer during project formulation.[18]

Conclusions

In concluding this socio-political section on implementation, it should be emphasized that value of this implementation prediction approach is not in its quantitative accuracy, or outcome, but in offering a logical and quantitative format to develop conclusions, through their relative accuracy, as to predictable response of actor groups in public works decision processes, and thereby develop planning and engineering alternatives which have predictable potentials for compromise.

As is obvious, the engineer-planner must develop a capable insight into the actor groups and their preferences. This is axiomatic in modern public works implementation. The modified stochastic gaming model develop herein allows him to position himself in the decision process to make orderly and conclusive use of these insights, and offers a platform for negotiation with actor groups and a framework for developing meaningful changes in project location and site design alternatives.

SECTION D - REGIONAL STOL/VTOL INVESTMENT ANALYSIS

The objective of this section is the development of a framework for analysis of STOL/VTOL facility investments as components of the St. Louis metropolitan regional transportation system, serving as viable commuter alternatives, and having recognizable impact on land use, growth and economic issues associated with regional transportation resources.

Specifically, the analysis will seek to discover if: STOL/VTOL is a commuter alternative to others proposed for a metropolitan region such as St. Louis; what are the user costs, benefits and subsidy assumptions, and are there particular regional growth states and/or economic patterns which STOL/VTOL investment are particularly suited, or not suited for. The following discussion unfolds the analytic approach using Markovian Decision Theory, the testing of a STOL/VTOL system along with other transportation options in the St. Louis region, and integrates appropriate regional economic and environmental issues into the analysis. Conclusions with respect to the above are presented in Chapter VI.

Problem Structure

The problem structure is developed by the quantification of several system attributes; the system state space, appropriate transportation alternatives, transition probabilities, and state rewards. These will be elaborated on below, and integrated to activate the analysis.

System States

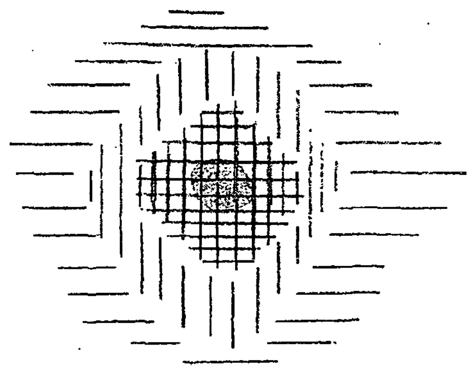
The formal state space reflects the prominence of various regional activities, and associated development patterns. Each state can be described by value levels of critically descriptive state variables. In this analysis, the following variables are used to form the state definition: a.) population density, b.) non-residential core floor space, c.) non-residential corridor floor space, d.) regional value added, and e.) total personal income. As such, five recognizable states of regional development were identified, which are: core dominant, corridor dominant, satellite communities (non-core dominant), land use dormant (region stable) and land use in decline (region unstable). The states and the corresponding threshold variable values are presented in Table 59, and are schematically depicted in Figure 28. Thus, as is obvious

Figure 28

ALTERNATIVE STATES OF METROPOLITAN ST. LOUIS REGIONAL

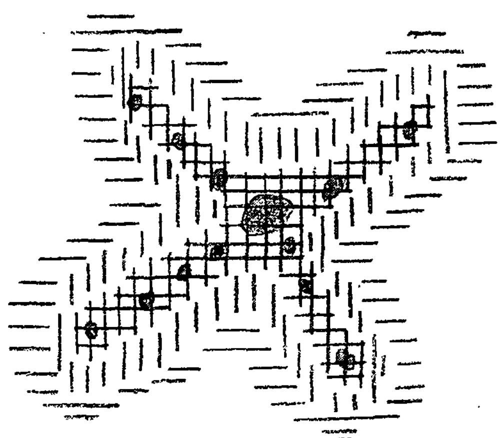
DEVELOPMENT

1. Core Dominant



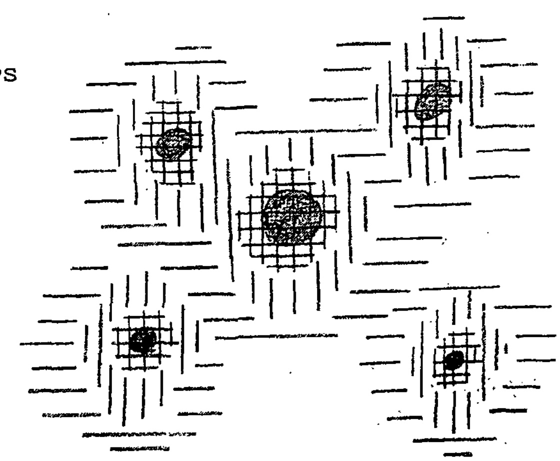
Activity Center
High Density
Medium Density
Low Density

2. Corridor Dominant



Activity Center
High Density
Medium Density
Low Density

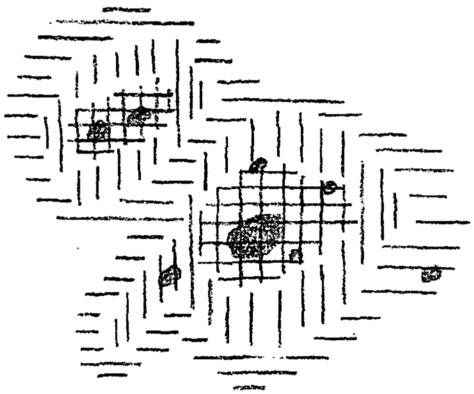
3. Satellite Centers



Activity Center
High Density
Medium Density
Low Density

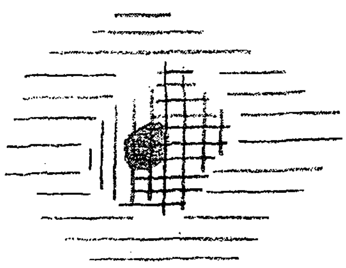
Figure 28 continued

4. Region Stable



Activity Center
High Density
Medium Density
Low Density

5. Region in Decline



Activity Center
High Density
Medium Density
Low Density

TABLE 59

ST. LOUIS REGION STATE SPACE FORMULATION

STATE	VARIABLE	
Core Dominant	a_1	$\geqq$ 40% increase (core)
	b_1	$\geqq$ 200% increase
	c_1	not apply
	d_1	$\geqq$ 100% increase
	e_1	$\geqq$ 70% increase
Corridor Dominant	a_2	$\geq$ 100% increase (corridor)
	b_2	$\geq$ 40% increase
	c_2	$\geq$ 200% increase
	d_2	$\geq$ 100% increase
	e_2	$\geq$ 70% increase
Satellite Communities	a_3	$\geq$ 300% increase
	b_3	$<$ 40% increase
	c_3	200% increase (satellite)

TABLE 59 continued

STATE	VARIABLE
Satellite (cont.) Communities	d_3 $\geq$ 100% increase
	e_3 $\geq$ 70% increase
Land Use Dormant	a_4 $< a_1, a_2, a_3$
	b_4 $< b_1, b_2, b_3$
	c_4 $< c_1, c_2, c_3$
	d_4 50% increase
	e_4 40-70% increase
Land Use in Decline	a_5 $< a_1, a_2, a_3, a_4$
	b_5 $< b_1, b_2, b_3, b_4$
	c_5 $< c_1, c_2, c_3, c_4$
	d_5 <50% increase
	e_5 <40% increase

core dominance reflects a major revitalization of downtown, corridor dominant reflects a definite controlled non-residential growth along major corridors, a satellite city concept reflects balancing of regional dominance through several outlying "growth centers". The land use dormant state reflects the status quo, and the region in decline reflects a status quo, or loss of income producing land, with the region in a worsened position as measured by economic criteria. The associated floor space and income levels describing each state are those threshold levels which have typically accompanied the particular spatial description of a specific growth pattern.

Transportation Alternatives

The formalized transportation alternatives were selected on the basis of current options under study in the metropolitan St. Louis Comprehensive Transportation Study, and are shown in Figure 18.[19] These are described below, in addition to the STOL/VTOL option included for analysis.

The first alternative represents a program of highway improvements of a limited nature; basically, completing work only on projects currently scheduled for completion in 20 years. This represents approximately 50 miles of construction of new facilities and

13

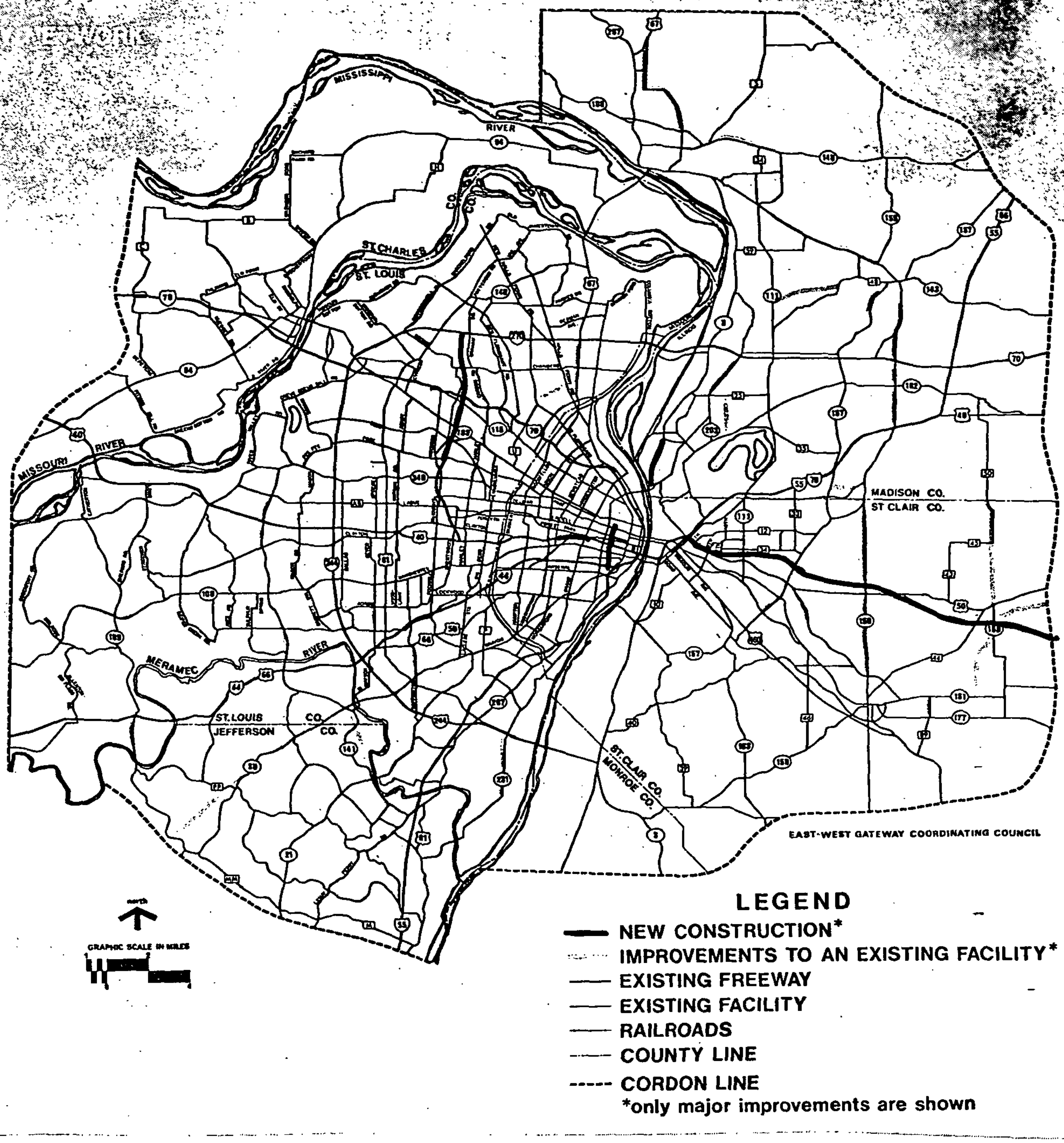


Figure 29

ALTERNATIVE 1

Source: The 1995 Highway and Transit Plan for the St. Louis Area, A Review and Update", East-West Gateway Coordinating Council, St. Louis, MO, March 1974.

13

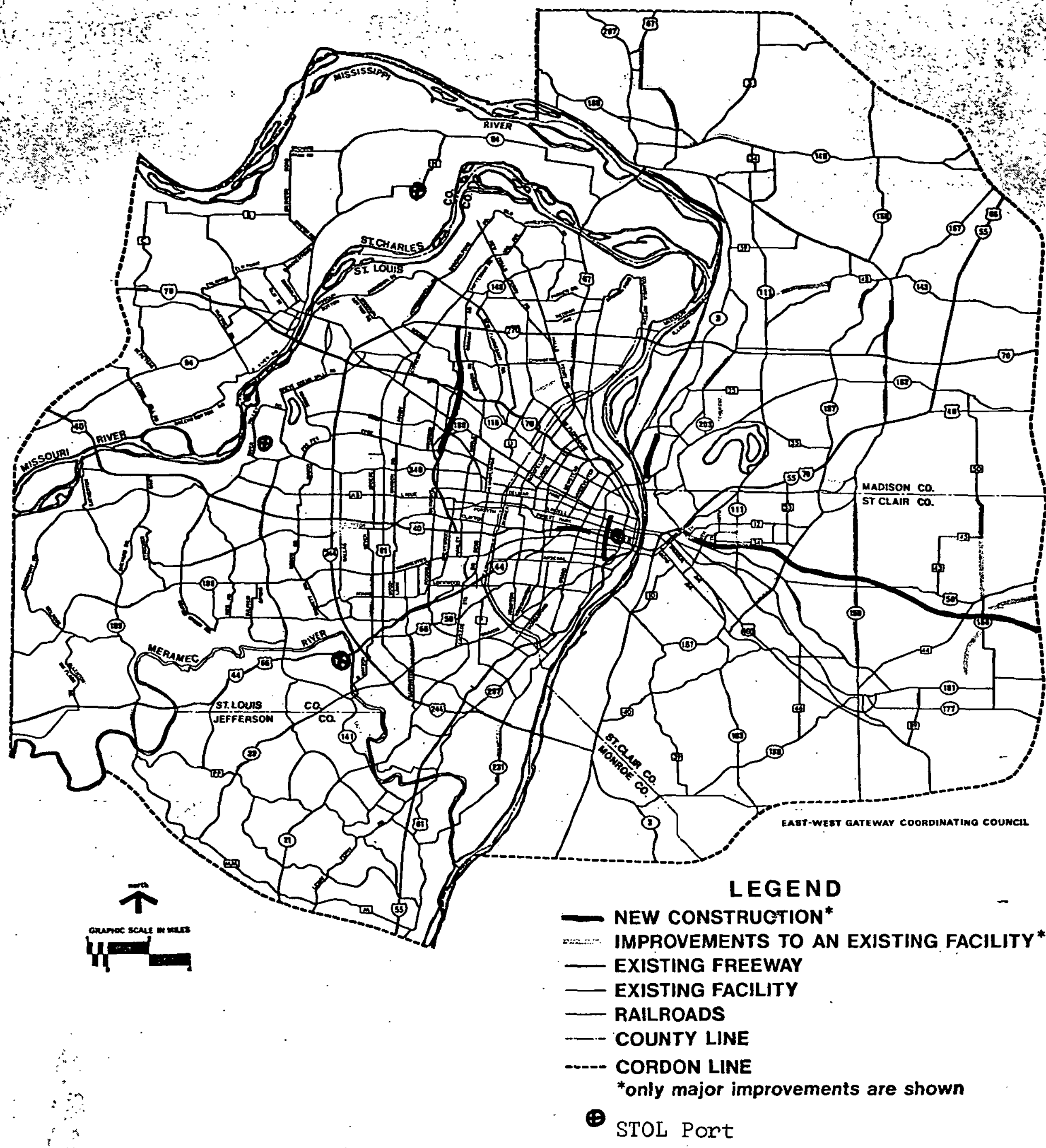


Figure 30

ALTERNATIVE 2

Source: The 1995 Highway and Transit Plan for the St. Louis Area, A Review and Update", East-West Gateway Coordinating Council, St. Louis, MO, March 1974.

13

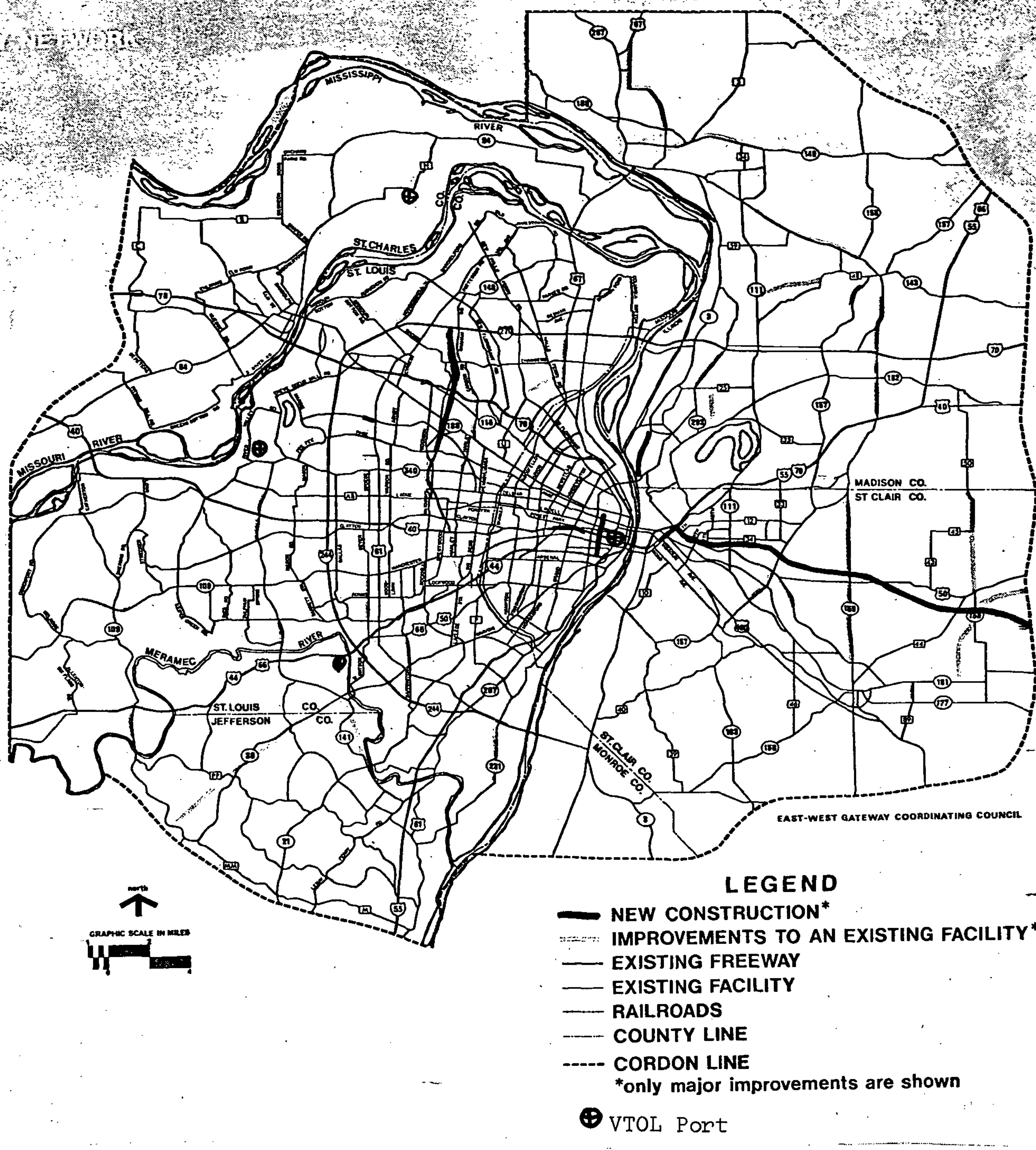


Figure 31

ALTERNATIVE 3

Source: The 1995 Highway and Transit Plan for the St. Louis Area, A Review and Update", East-West Gateway Coordinating Council, St. Louis, MO, March 1974.

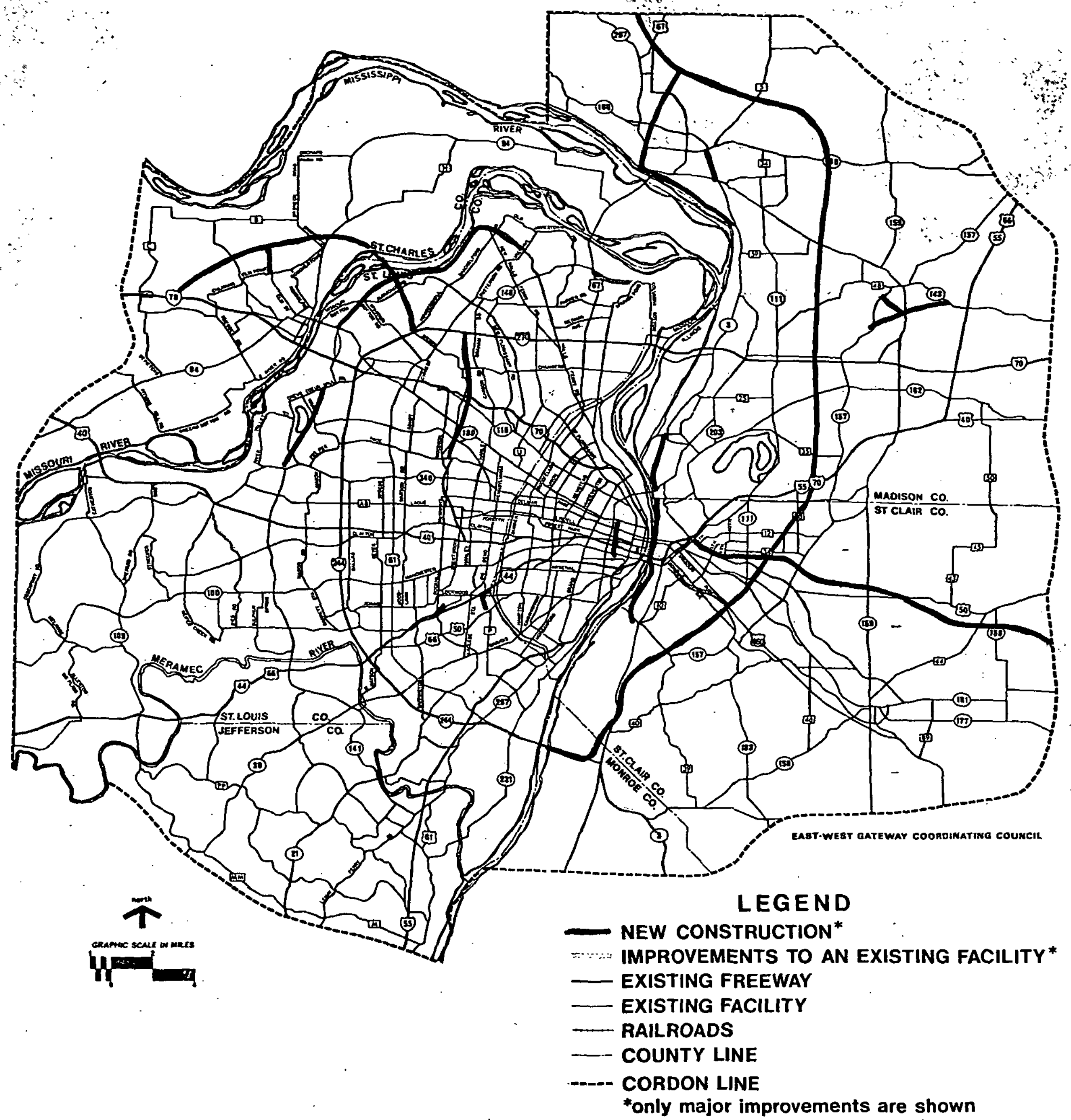


Figure 32

ALTERNATIVE 4

Source: The 1995 Highway and Transit Plan for the St. Louis Area, A Review and Update", East-West Gateway Coordinating Council, St. Louis, MO, March 1974.

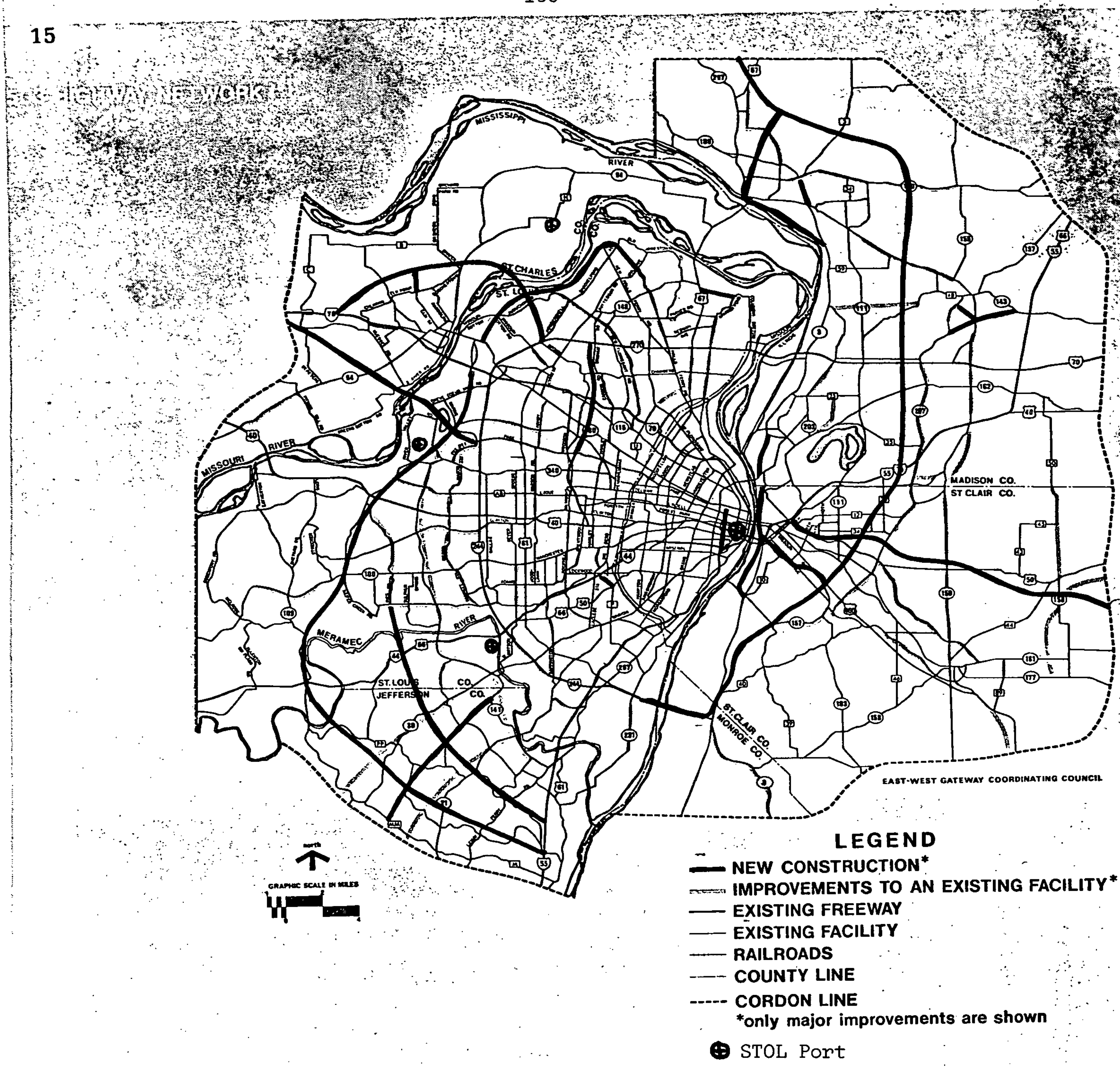


Figure 33

ALTERNATIVE 5

Source: The 1995 Highway and Transit Plan for the St. Louis Area, A Review and Update", East-West Gateway Coordinating Council, St. Louis, MO, March 1974.

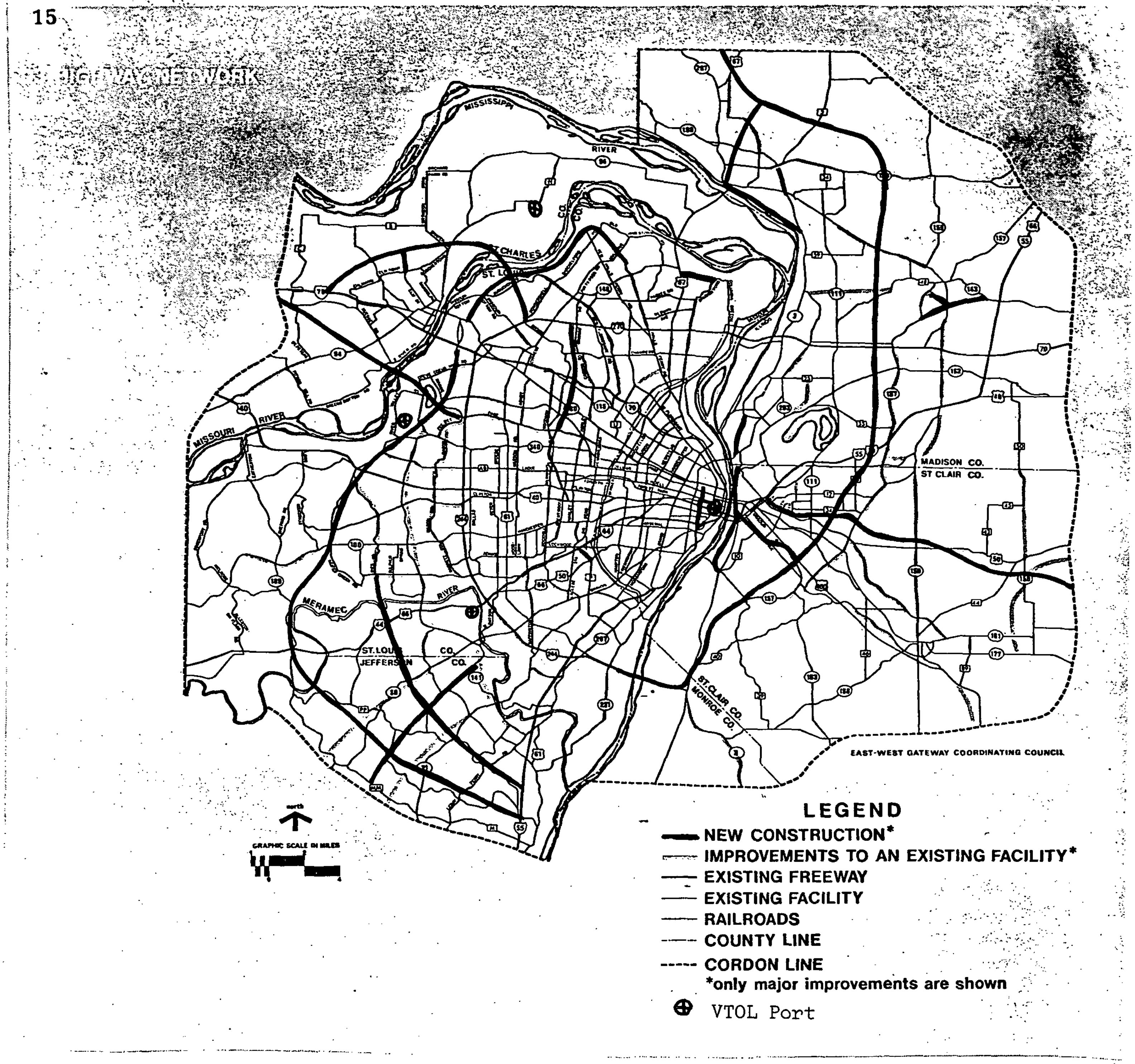


Figure 34

ALTERNATIVE 6

Source: The 1995 Highway and Transit Plan for the St. Louis Area, A Review and Update", East-West Gateway Coordinating Council, St. touis, MO, March 1974.

375 miles of improvements to existing major roadways. The total system would be composed of approximately 250 miles of freeways and 1300 miles of major arterials, totalling to 1550 miles of major roadway facilities.

Alternative two combines the above limited highway improvement alternative with a STOL commuter system. The STOL system would involve three STOL Port facilities located approximately 25 miles from a STOL port in the central core area, for a total of four regional STOL ports.

The third alternative again includes the limited highway improvements of alternative one, and couples these with a VTOL system. This system would spatially consist of three peripheral VTOL ports plus a downtown port.

The fourth alternative is a moderate highway, and major transit improvement program. This alternative involves the previous limited highway improvements program, plus 170 miles of new facilities and 600 more miles of improvements to existing major facilities, yielding a total metropolitan highway component of approximately 300 miles of freeways, and 1360 miles of arterials. In addition, a transit component is included which would consist of a proposed 100 mile set of rail rapid transit trunk lines, plus extension to three

outlying activity centers, with appropriate feeder bus service throughout the region. The total transit system thus includes 151 miles of rail rapid transit, plus a feeder bus system of 2716 route miles.

Alternative five is also composed of two parts. The first part is a major highway improvement program, in addition to the limited improvements of the first alternative. A total of 270 miles of new highways would be added plus improvements to 780 existing miles of highways. The total major roadway mileage would be 1700 miles, composed of 300 miles of freeways and 1400 miles of arterials. The second component of this alternative is a regional STOL system identical to that described in the second alternative.

Alternative six involves the major highway improvement program described in alternative five, plus a VTOL system, as outlined for alternative three.

Transition Probabilities

The matrix of transition probabilities is composed of the probabilities of the system, currently in state i, moving to state j, in the next transition. Here the transition time period is ten years, which reflects the time span required for land use patterns

to develop recognizable shifts which have regional growth implications. The properties of probability measures of relevance are:

$$\sum_{J=1}^{N} P_{ij} = 1 \qquad \text{where } i = 1,2, \ldots N \text{ for N states}$$

$$0 \leq P_{ij} \leq 1$$

A P_{ij} matrix also exists for each alternative, and we have

$$P^k = \begin{bmatrix} P_{ij} \end{bmatrix}^k$$

where k = 1,2, ... 6 for the six alternatives under study. This reflects the inherent degree of association of changes of regional growth patterns by virtue of employment of particular types of transportation investment, and the classic land use-transportation feedback mechanism. These transition probability matrices are presented in Table 60 for each alternative. The values in the Table reflect historical and research knowledge of the effect a particular transportation system has on land use patterns, as well as prevailing and likely future trends in regional land use patterns. In addition, by theorizing that the system can behave as an ergodic markov process, the steady state probabilities π_i are also presented over the various alternatives. These are the long run probabilities that the system will be found in a particular state i at any time of investigation t.

Reward Matrices

The reward matrices for the states of the system reflect the gains to the regional system in its transition from state i to state j during the next 10 year time interval. Here again, the reward matrix is specific to the individual transportation alternatives due to differing costs and beneficial impacts of employing a specific transportation alternative. Notationally we have:

$$R^k = \left[r_{ij} \right]^k \qquad \text{where } i, j = 1,2, \ldots 5$$
$$k = 1,2, \ldots 6$$

The final reward matrices for the various alternatives are presented in Table 60 through Table 66. Two major approaches were employed in arriving at the reward values, r_{ij}^k. Each will now be detailed below.

Value Added Approach

The transition from state i to j, will yield an alteration in dollar value of regional activity. A reasonable surrogate for regional value added is total income generated through addition of non-residential floor space. Thus, a reward matrix of shifts in regional value added due to the existence of different states and associated transportation alternatives could be developed. Current practice indicates the average building cost of commercial and

TABLE 60

STATE TRANSITION PROBABILITIES
and
STEADY STATE PROBABILITIES

Alternative	State	1	2	3	4	5	Steady π_i State
1	1	.50	.10	.10	.20	.10	.162
	2	.20	.40	.20	.10	.10	.193
	3	.05	.20	.60	.10	.05	.272
	4	.05	.15	.20	.40	.20	.166
	5	.10	.10	.10	.10	.60	.206
2	1	.30	.20	.30	.15	.05	.194
	2	.20	.25	.40	.10	.05	.199
	3	.20	.20	.50	.05	.05	.354
	4	.10	.20	.20	.40	.10	.140
	5	.10	.10	.10	.15	.55	.114
3	1	.35	.20	.35	.05	.05	.244
	2	.25	.20	.40	.10	.05	.165
	3	.25	.15	.50	.05	.05	.385
	4	.10	.15	.25	.40	.10	.105
	5	.10	.10	.15	.15	.50	.100
4	1	.20	.40	.30	.08	.02	.180
	2	.20	.60	.15	.04	.01	.434
	3	.20	.30	.30	.15	.05	.208
	4	.10	.25	.15	.40	.10	.126
	5	.05	.15	.15	.25	.40	.052
5	1	.20	.35	.35	.05	.05	.169
	2	.15	.45	.25	.10	.05	.349
	3	.20	.30	.35	.10	.05	.285
	4	.15	.30	.20	.30	.05	.119
	5	.10	.15	.20	.15	.40	.077
6	1	.20	.30	.40	.05	.05	.166
	2	.15	.40	.30	.10	.05	.296
	3	.20	.25	.40	.10	.05	.344
	4	.10	.25	.30	.30	.05	.126
	5	.10	.15	.20	.15	.40	.068

TABLE 61 REWARD MATRIX ALTERNATIVE 1

STATE	1	2	3	4	5
1	2751	-1031	-1574	-2312	-2560
2	1652	1686	-510	-251	-1412
3	1642	577	1142	-385	-610
4	2381	593	514	731	-1217
5	2627	1512	987	1178	239

($ X 10^6)

TABLE 62 REWARD MATRIX ALTERNATIVE 2

STATE	1	2	3	4	5
1	2758	-1024	-1567	-2305	-2553
2	1659	1693	-503	-244	-1405
3	1649	584	1149	-378	-603
4	2388	600	521	738	-1210
5	2634	1519	994	1185	246

($ X 10^6)

TABLE 63 REWARD MATRIX ALTERNATIVE 3

STATE	1	2	3	4	5
1	2754	-1028	-1571	-2309	-2558
2	1655	1689	-507	-248	-1409
3	1645	580	1145	-382	-607
4	2384	596	517	734	-1214
5	2630	1515	990	1181	246

($ X 10^6)

TABLE 64 REWARD MATRIX ALTERNATIVE 4

STATE	1	2	3	4	5
1	2842	-940	-1483	-2221	-2469
2	1743	1777	-419	-160	-1321
3	1733	668	1233	-294	519
4	2472	681	605	822	-1126
5	2718	1603	1078	1269	330

($\$ \times 10^6$)

TABLE 65 REWARD MATRIX ALTERNATIVE 5

STATE	1	2	3	4	5
1	2458	-806	-1349	-2065	-2335
2	1877	1911	-285	-26	-1187
3	1867	802	1367	-160	-385
4	2606	818	739	956	-992
5	2852	1737	1212	1403	464

($\$ \times 10^6$)

TABLE 66 REWARD MATRIX ALTERNATIVE 6

STATE	1	2	3	4	5
1	2454	-810	-1353	-2069	-2339
2	1873	1907	-289	-30	-1191
3	1863	798	1363	-164	-389
4	2602	814	735	952	-996
5	2848	1733	1208	1399	460

($\$ \times 10^6$)

industrial floor space is \$11.00/sq. ft. If a 12% profit is allowed the builder, this indicates a primary monetary gain to the system of \$12.32 for each square foot of additional commercial or industrial floor space constructed.[19] Therefore, based on the state characteristics b_n, c_n for $n = 1,2,..,5$, a crude approximation figure can be reached for the additional change in primary monetary effects on the region due to floor space that will be added in each of the states.

The second component of r_{ij}^k is the classical net benefits evaluation of user savings and costs associated with particular transportation alternatives. Development of these cash flow parameters utilized value of time employed in the analysis of STOL/VTOL systems of the previous sections. Therefore, the element:

$$r_{ij}^k = V^k + NB^k$$

where: V^k = \$value generated through change in non-residential construction

NB^k = user net benefits of alternative k.

The Markovian solution for the model was carried over two ten year iterations to be compatible with the 20 year transportation planning horizon used in the St. Louis Region.

Interpretation

The Markovian solution approach maximizes the test quantity $q^k + \sum P_{ij}^k V_j^k$ for each state of the system overall alternatives.[20] For a complete coverage of the mathematics see Appendix C. However, one modification was established: due to the long lead time of constructing facilities within the planning horizon, and the sunk cost, inflexible nature of system-wide transportation programs, it was presumed, for purposes of model computation, that the system as chosen optimal through analysis would be held constant as to implementation policies of the chosen alternative over the 20 year horizon period. Thus, there would be no "totally shelving the adopted plan" as is often done in the real world midway through a planning horizon, based on annual updates.

The solution approach involves the maximization of the test quantity over each state of the system. The values for this quantity for the various alternatives are given in Table 67. The alternative that maximizes this quantity is then selected for each state. This decision or policy vector of optimal alternatives over all states is presented in Table 68 along with the maximized values of $q_i^k + \sum P_{ij}^k V_j^k$.

These results indicate the optimal transportation alternative to be implemented. In other words, given the current state of the system,

TABLE 67

COMPUTATION OF TEST QUANTITIES

ALTERNATIVE 1

State	Q(i)	V(i) First Iteration	V(i) Second Iteration	$q_i^1 + \sum P_{ij}^1 V_j^1$
1	396.6	-377.2	-569.5	125.4
2	736.7	-37.1	-81.9	613.0
3	813.7	39.9	74.7	769.6
4	359.8	-414	-517.3	177.6
5	773.8	0	0	694.9

Q(I), V(I) in $\$10^6$

ALTERNATIVE 2

STATE	Q(i)	V(i) First Iteration	V(i) Second Iteration	$q_i^2 + \sum P_{ij}^2 V_j^2$
1	-320.9	-1148.7	-1391.4	-734.7
2	459.2	-419.6	-484.5	172.2
3	972.1	144.3	64.5	721.2
4	637.2	-190.6	-256.6	391.1
5	827.8	0	0	656.7

Q(I), V(I) in $\$10^6$

ALTERNATIVE 3

State	Q(i)	V(i) First Iteration	V(i) Second Iteration	$q_i^3 + \sum P_{ij}^3 V_j^3$
1	-35.0	-898.2	-1129.8	-419.7
2	453.5	-409.7	-1119.8	156.1
3	943.0	79.8	-24.3	685.8
4	629.3	-233.9	-304.8	405.3
5	863.2	0	0	710.1

ALTERNATIVE 4

STATE	Q(i)	V(i) First Iteration	V(i) Second Iteration	$q_i^4 + \sum P_{ij}^4 V_j^4$
1	-479.6	-1466.9	-2305.6	-806
2	1061.7	74.4	-64.3	781.7
3	846.8	-140.5	-344.2	494.5
4	724.5	-262.8	-367.7	471
5	987.3	0	0	838.7

ALTERNATIVE 5

STATE	Q(i)	V(i) First Iteration	V(i) Second Iteration	$q_i^5 + \sum P_{ij}^5 V_j^5$
1	-482.8	-1613.1	-1847.4	-862.7
2	1008.4	-100.	-284.8	699.9
3	1057.2	-51.2	-306.7	678
4	1021.3	-87.1	-271.7	713
5	1184.3	0	0	984.7

ALTERNATIVE 6

STATE	Q(i)	V(i) First Iteration	V(i) Second Iteration	$q_i^6 + \sum P_{ij}^6 V_j^6$
1	-513.9	-1694.2	-1900.4	-991.2
2	+894.1	-206.2	-410.6	469.8
3	1081.4	-98.9	-303.7	605.5
4	920	-260.3	-337.9	571.3
5	1180.3	0	0	909.2

TABLE 68

POLICY VECTOR

STATE	POLICY k	$q_i^k + \sum P_{ij}^k V_j^{k*}$
1	1	125.4
2	4	781.7
3	1	769.6
4	5	713.0
5	5	984.7

* (X 10^6 dollars)

state i, the system will maximize its value twenty years hence by implementing alternative $k.^{*}$ The test quantity is equal to:

$$q_i^k + \sum_{j=1}^{n} P_{ij}^k V_{ij}^k = V_i^k + g^k$$

where

$$V_i^k + g^k$$

is the value of currently being in state i plus the gain g to the system due to implementing specific alternative k. The complete illustration of such results is shown in the policy vector of Table 68. For example, given the system currently in state one, then policy one will maximize the system value plus gain with a value of $\$125.4 \times 10^6$. Similarily, policy four will maximize this system reward with $\$781.7 \times 10^6$. For states three, four and five, policies one, five and five respectively, will maximize the system rewards with the respective values of $\$769.6 \times 10^6$, $\$713.0 \times 10^6$, and $\$984.7 \times 10^6$. These dollar values represent the monetary value accruing to the system after two ten year transitions, based on the r_{ij}^k input as defined previously.

Examination of the policy vector yields some interesting conclusions. The limited highway alternative 1 is invoked if the system is presently in either a core dominant or satellite state. An interpretation is that the region would only suffer reverses

through implementing other major transportation alternatives which yielded opportunities for regional dispersal of activities thus defeating the objective of state 1, or providing opportunities for an over abundance of satellite center attempts, ultimately yielding ineffective exploitation of state four. The corridor dominant state 3 is obviously enhanced by alternative 4, with associated spinal growth patterns along the transit and highway alignments. The status quo and regional declining land use, states 5 and 6, respectively, both optimize on major highway construction in conjunction with a regional STOL system. This has a tenative interpretation that a regional STOL investment may have a certain constructive "shock" value to a region in need of increased activity. This may result from the input of another transportation entity, and the associated land use and circulation changes in the vicinity of the STOL ports. Altered commuter and recreational travel patterns and regional opportunities may result, due to the presence of an alternative form of travel, and potential user invocation of a higher value of travel time.

Value Matrix Approach for Input of r_{ij}^{k}.

This section develops an alternate approach to r_{ij}^{k} formulation, to incorporate social and environmental concerns, along with regional economic wealth criteria in the analysis. It follows a format similar to section B, in the peripheral development model. First each alternative is ranked according to its attainment of a certain impact, i.e. capital cost, noise pollution, levels of relevant regional value added, etc. Each alternative receives a value of 1 through 6 depending on its position relative to the other alternatives under consideration.

Next, the impact factors are weighted for each state of the system. This is necessitated by the fact that certain impacts are of greater consequence for various system states. For example, noise and air pollution are extremely important in the core dominant state while energy costs occupy a much more prominent weight in the third state, that of the satellite cities concept.

Each alternative is then given a score based on the rank value and associated weight. This score is determined by:

$$\text{score}_{ik} = \sum_{x=1}^{m} r^{k} w_{x}$$

where i = state of system $i = 1,2..,5$

k = alternative $k = 1,2..,6$

r^k = rank value of that alternative

w_x = weight of that impact

x = number of impacts $\quad x = 1, 2 \ldots, 7.$

The various values for the rank values, weights, and scores are presented in Tables 69 through 73. It should be noted that both capital cost and net benefits are included in the impacts. Although this may appear to be double counting, review of recent UMTA ground transportation decisions reveals that federal decision-makers are highly sensitive to the pure capital costs of a sunk cost system, regardless of B/C ratios. Hence, both are included, to adequately portray the user benefits relative to costs incurred, and the sensitivity to pure capital cost. The highest possible score would be 168, reflecting an alternative rank of 6 for each of the 7 impacts. Reward matrices R_{ij}^k are then calculated. Here R_{ij}^k is defined by:

$$r_{ij}^k = (\text{score}_{jk}) - (\text{score}_{ik}) \qquad i = j$$

and by

$$r_{ij}^k = \text{score}_{ik} \qquad i = j$$

with the terms as defined previously. These reward matrices for each alternative are presented in Tables 74 through 79.

The solution technique is the same as that previously described. A policy vector, shown in Table 80, is determined with an element for each state of the system. This policy element is that transportation alternative which will yield the highest level of impact acheivement after two ten year periods.

TABLE 69

VALUE MATRIX ON IMPACTS, STATE 1

IMPACT FACTOR	FACTOR WEIGHTING	ALTERNATIVE											
		1		2		3		4		5		6	
1. Capital Cost	4	6	24	5	20	4	16	1	4	3	12	2	8
2. Noise	6	6	36	5	20	4	24	3	18	2	12	1	6
3. Pollution	7	3	21	2	14	1	7	6	42	5	35	4	28
4. Regional Value Added	2	1	2	2.5	5	2.5	5	6	12	4.5	9	4.5	9
5. Total Personal Income	5	1	5	2	10	3	15	4	20	5	25	6	30
6. Energy Cost	1	3	3	2	2	1	1	6	6	5	5	4	4
7. Net Benefits	3	1	3	3	9	2	6	6	18	5	15	4	12
			94		80		74		120		113		97

TABLE 70

VALUE MATRIX ON IMPACTS STATE 2

IMPACT FACTOR	FACTOR WEIGHTING	ALTERNATIVE											
		1		2		3		4		5		6	
1. Capital Cost	5	6	30	5	25	4	20	1	5	3	15	2	10
2. Noise	3	6	18	5	15	4	12	3	9	2	6	1	3
3. Pollution	1	3	3	2	2	1	1	6	6	5	5	4	4
4. Regional Value Added	7	1	7	2.5	17.5	2.5	17.5	6	42	4.5	31.5	4.5	31.5
5. Total Personal Income	6	1	6	2	12	3	18	4	24	5	30	6	36
6. Energy Cost	4	3	12	2	8	1	4	6	24	5	20	5	16
7. Net Benefits	2	1	2	3	6	2	4	6	12	5	10	5	8
			78		85.5		76.5		122		117.5		108.5

TABLE 71

VALUE MATRIX ON IMPACTS STATE 3

IMPACT FACTOR	FACTOR WEIGHTING	ALTERNATIVE											
		1		2		3		4		5		6	
1. Capital Cost	5	6	30	5	25	4	20	1	5	3	15	2	10
2. Noise	2	6	12	5	10	4	8	3	6	2	4	1	2
3. Pollution	1	3	3	2	2	1	1	6	6	5	5	4	4
4. Regional Value Added	6	1	6	2.5	15	2.5	15	6	36	4.5	27	4.5	27
5. Total Personal Income	4	1	4	2	8	3	12	4	16	5	20	6	24
6. Energy Cost	7	3	21	2	14	1	7	6	42	5	35	4	20
7. Net Benefits	3	1	3	3	9	2	6	6	18	5	15	4	12
			79		83		69		129		121		101

TABLE 72

VALUE MATRIX ON IMPACTS STATE 4

IMPACT FACTOR	FACTOR WEIGHTING	ALTERNATIVE											
		1		2		3		4		5		6	
1. Capital Cost	6	6	36	5	30	4	24	1	6	3	18	2	12
2. Noise	4	6	24	5	20	4	16	3	12	2	8	1	4
3. Pollution	5	3	15	2	10	1	5	6	30	5	25	4	20
4. Regional Value Added	1	1	1	2.5	2.5	2.5	2.5	6	6	4.5	4.5	4.5	4.5
5. Total Personal Income	7	1	7	2	14	3	21	4	28	5	35	6	42
6. Energy Cost	2	3	6	2	4	1	2	6	12	5	10	4	8
7. Net Benefits	3	1	3	3	9	2	6	6	18	5	15	4	12
			92		89.5		73.5		112		115.5		102.5

TABLE 73

VALUE MATRIX ON IMPACTS STATE 5

IMPACT FACTOR	FACTOR WEIGHTING	ALTERNATIVE 1		2		3		4		5		6	
1. Capital Cost	4	6	24	5	20	4	16	1	4	3	12	2	8
2. Noise	1	6	6	5	5	4	4	3	3	2	2	1	1
3. Pollution	2	3	6	2	4	1	2	6	12	5	10	4	8
4. Regional Value Added	7	1	7	2.5	11.5	2.5	11.5	6	42	5	31.5	4.5	31.5
5. Total Personal Income	6	1	6	2	12	2	18	4	24	5	30	6	36
6. Energy Cost	3	3	9	2	6	1	3	6	18	5	15	4	12
7. Net Benefits	5	1	5	3	15	2	10	6	30	5	25	4	20
			63		79.5		70.5		133		125.5		116.5

TABLE 74 REWARD MATRIX ALTERNATIVE 1

STATE	1	2	3	4	5
1	94	-16	-15	-2	-31
2	16	78	1	+14	-15
3	15	-1	79	13	-16
4	2	-14	-13	92	-29
5	31	15	16	29	63

TABLE 75 REWARD MATRIX ALTERNATIVE 2

STATE	1	2	3	4	5
1	80	5.5	3	9.5	-.5
2	-5.5	85.5	-2.5	4	-6
3	-3	2.5	83	6.5	-3.5
4	-9.5	-4	-6.5	89.5	-10
5	.5	6	3.5	10	79.5

TABLE 76 REWARD MATRIX ALTERNATIVE 3

STATE	1	2	3	4	5
1	74	2.5	-5	-.5	-3.5
2	-2.5	76.5	-7.5	-3	-6
3	5	7.5	69	4.5	1.5
4	.5	3	-4.5	73.5	-3
5	3.5	6	-1.5	3	70.5

TABLE 77 REWARD MATRIX ALTERNATIVE 4

STATE	1	2	3	4	5
1	120	2	9	-8	13
2	-2	122	7	-10	11
3	-9	-7	129	-7	4
4	8	10	7	112	21
5	-13	-11	-4	-21	133

TABLE 78 REWARD MATRIX ALTERNATIVE 5

STATE	1	2	3	4	5
1	113	4.5	8	2.5	12.5
2	-4.5	117.5	3.5	-2	8
3	-8	-3.5	121	-5.5	4.5
4	-2.5	2	5-5	115.5	10
5	-12.5	-8	-4.5	-10	125.5

TABLE 79 REWARD MATRIX ALTERNATIVE 6

STATE	1	2	3	4	5
1	97	11.5	4	5.5	19.5
2	-11.5	108.5	-7.5	-6	8
3	-4	7.5	101	1.5	15.5
4	-5.5	6	-1.5	102.5	14
5	-19.5	-8	-15.5	-14	116.5

TABLE 80

IMPACT ANALYSIS POLICY VECTOR, SECOND ITERATION

State	Test Quantity $q_i^k + \sum_{j=1}^{n} P_{ij}^k V_j^k$							
	Alternative						Max.	Policy
	1	2	3	4	5	6		
1	31.6	12.7	15.4	32.5	24.6	26.0	32.5	4
2	26.3	5.9	6.1	86.0	52.7	44.4	86.0	4
3	43.9	29.3	30.7	36.6	35.3	42.2	43.9	1
4	15.8	17.6	20.1	61.9	34.2	31.1	61.9	4
5	43.0	39.0	32.1	48.6	42.2	37.7	48.6	4

As shown, given the system in state one, the core dominant case, the fourth transportation alternative of moderate highway and major transit improvements will produce the optimal reward set in terms of the impact herein analyzed. Similarily, for state two again alternative four maximizing the impacts. For state three, four, and five alternatives one, four and four maximizing the impacts respectively.

As can be noted from comparing this policy vector to the previous one, substantial alterations of optimal choices of alternatives occur when the broadened impact criteria are included in the analysis. The moderate highway and transit alternative was dominant for all regional states except the satellite city concept of state 3. Alternative 4 apparently fits regional value structure so developed herein, with a minimum of environmental and energy costs, regardless of the present patterns of growth state of the region. The optimizing of the satellite city concept, state 3, by a limited highway program, can be interpreted as a statement of not exploiting opportunities for further regional outlying centers past their level of existence found in state 3, due to ultimate inefficiency of patterns of energy use, and potential environmental effects brought on by new highway construction as required to further disperse the region. STOL or VTOL options were not optimal for any state in this broadened analysis, due to implications of

energy cost, levels of user net benefits and system capital investments, in light of the regional value structure imposed on the analysis.

FOOTNOTES

1 pg. 80, Figure 23, STOL InterMetropolitan Evaluation Phase X, January 1970, American Airlines, N.Y.

2 Table 8, Origin-Destination Survey of Airline Passenger Traffic (Domestic) Second Quarter 1974, Compiled by the C.A.B.

3 Ibid.

4 Ibid.

5 Reference 3, John Hosford, McDonnell Douglas Company, unpublished material, pg. I-3 Further Studies in Short Hail Air Transportation in the California Corridor, Richard S. Shevell, July 1974, NASA-Ames Research Center, Contract No. NAS2-7199.

6 pg. 4, Table 2. Alternative Policies for Effecting Intercity Energy Use Reduction, by Saul Sokolsky, October 3, 1974, The Aerospace Corporation.

7 J.R. Smith. District Supervisor, Western Division, Greyhound Lines, Inc. Paul H. Orr, District Sales Manager National Railroad Passenger Corporation Amtrak

8 David Wuenscher, Richard Odebrecht, Real Estate Research Corporation.

9 Ibid.

10 Hotel construction cost = 1000 X (# of rooms) *(average daily occupancy rental in dollars)

11 Technical and Economic Evaluation of Aircraft for Intercity Short-Haul Transportation, April 1966, for F.A.A. by McDonnell Aircraft Corporation, FA6SWA-1246

12 C.A.B. Airline O-D book

13 Western Region Short-Haul Air Transportation Program Report, Volume 2, p. 6-4

14 Study of Quiet Turbofan STOL Aircraft for St. Louis Transportation First Report pp. 208-213, MAC Report

15 Ibid. p. 216

16 Haefner, Dr. Lonnie E., "Volume I: A State-of-the-Art Review of Transportation Systems Evaluation Techniques Relevant to Air Transportation" Washington University, St. Louis, MO., NASA Contract NAS2-8324, August 28, 1975.

17 Interview with Mr. A. Michenfelder Jr., April 4, 1975. Also, a review of the background studies for and the actual zoning petition number 182-73 by Mallinckrodt Corporation, February 8, 1974, aided in the prediction of the initial responses of several actor groups.

18 Haefner, Lonnie E., Redding, Marlin J., "An Analytical Structure of Community Public Works Decision Process," Department of Civil Engineering, University of Maryland, Office of Environment and Urban Systems, Department of Transportation.

19 "The 1995 Highway and Transit Plan for the St. Louis Area A Review and Update", East West Gateway Coordinating Council, St. Louis, MO, March 1974.

20 Interview with Mr. Dave Wuenscher and Mr. Dick Odebrecht. These income impacts have been treated by Isard, Walter, "Methods of Regional Analysis," Technology Press of Massachusetts Institute of Technology, Cambridge, Mass., 1960.

21 This test quantity is the adaptive gain to the system due to a transition from state i to j using alternative k. It consists of two terms: q^k, which is the immediate gain due to the transition, and $\sum P_{ij}^k U_j^k$, which is the total system value up to the current transition due to all previous possible transitions.

CHAPTER VI

CONCLUSIONS

As in any research endeavor, intensive association with the analytic efforts and policy and procedural issues which arise over the contract period yields some substantive conclusions from the research. In this particular study, conclusions are offered with respect to both the leverage and limitations offered by use of types of analytic techniques, and perspectives towards policy questions raised from the analysis of current air transport operations. These latter are often fruitful, even necessary areas for immediate further research.

General Conclusions in Dealing with Example Problems

1) Analytic methods can be used to test a carrier's preferred strategy in light of his organization's objectives and its economic health, particularly in the areas of scheduling, fare and route requests. Certain uncertainties in demand and weighting of objectives come into play, and simple statistical decision analysis can help to illuminate these

and test the strategy's preliminary sensitivity to them.

2) Likewise, a temporal analysis such as dynamic programming, along with reasonable cost analysis and projections, and capable monitoring, can allow more knowledgeable and defensible assembly of research and development program trajectories. Such program assembly in any R&D group has classically been difficult to achieve. An algorithmic synthesis of relevant combinations of options in light of federal trends does allow some logic and order to surface in the analysis and program defense. The problem must be kept to a manageable size, and made to internally function in a logical manner.

3) Certain scheduling phenomena, such as the rural commuter scheduling problem of Chapter IV, are difficult to analyze due to cumbersome scheduling alternatives open to the operator at a regional level. The capability of efficient development of scheduling alternatives, and/or accurate isolation of loss or gain associated with an option and the current travel demand is critical. Efficient analysis was possible by studying the system as a Markovian Decision Problem. Based on the example case study data and options studied in Chapter IV, operating losses for the travel

patterns were discovered. As such, the options open for consideration are:

a) A more creative set of scheduling and service patterns.

b) A highly truncated service pattern, which may be ineffective in regional travel benefits.

c) The issue of subsidies arises with several associated viewpoints:

   i) should free enterprise obtain, yielding less operators and/or extremely sparse service patterns?

   ii) should such rural development, growth and tourism be subsidized as an aggressive move towards good regional citizenship, parallel to the FHWA Economic Growth Highway Program? If so, who or what fraction of incidence should the subsidy fall on? Possibilities are the federal, state, region, communities serviced and/or resort and industrial sources who are enhanced.

Should this subsidy be given to a private operator or should the airline system be a state or regional jurisdictional ownership for public service, much like mass transit systems operating in urban metropolitan areas?

Case Study Analysis

1) Downtown Case

In development of analysis for the downtown case, simulation was found to be an appropriate analytic approach, due to its capability to employ various modal trip distributions in the analysis, and its ability to break the problem efficiently into a large number of individual entities, or modules, each of which are self-contained, and significant analysis issues in their own right. Linked to this, the capability to efficiently iterate over a series of subsidy figures against reasonable ranges of fare levels yielded appropriate output for the decision-maker. Against these analytic points, the following issues arise:

a) STOL/VTOL has an obviously improved opportunity to attempt to recover its terminal operation costs when operating as the anchor land use entity of a downtown transportation

center, due to the "shopper effect" of many opportune land uses and mode change opportunities being brought together at one contiguous site.

b) Again, due to fare and modal split conclusions, subsidy was found to be necessary. Who will subsidize STOL downtown?, the city, the downtown business core? As noted in the equations, no profit was figured in the STOL port operations. Thus, assuming the airport operates as a public entity, and offers a "magnet" to downtown use, this question of if and who will subsidize downtown STOL/VTOL is a crucial one.

2) Peripheral Development Case

The peripheral development case centers around a different focus than the above downtown complex. The issue is one of typical zoning, environmental and amenity analysis which comes forth in any major investment in the urban periphery.

a) A significant perspective of risk hedging on the part of the private developer and financier emerges, and can be treated quite well through the Bayesian Statistical Decision Theory Approach.
b) The critical part of such a Bayesian analysis is the development and sensitivity analysis of the levels of uncertainty

associated with the project's acceptance, integrated with cash flow analysis which is of importance to the private/ public works sector.

c) The key to implementation in the periphery is to offer a land use activity pattern which is Pareto Optimal to all participants in the decision. Such an alternative, while not dominantly optimal to any one party (such as would be the light and heavy industrial park for the developer) offers a compensation and inproved quality of life status for all parties as compared to the system prior to implementation.

3) Socio-Political Analysis

Closely related to the above, the socio-political analysis yields information which should be helpful in formulating the inputs to the peripheral model, and the STOL/VTOL regional investment analysis.

a) It is an attempt to position the analyst such that improved predictability can occur as to which public works project will be implementable, given actor group's responses to the alternatives offered.

b) The above is a very difficult problem, and has intonation

of sociological, attitudinal and psychological research most engineering decision-makers are unable to perform. As such, we are looking for a system which yields a simple set of signals, preferably quantitative ones, for interpretations of the potential ease of implementation of a project.

c) In light of the above, the modified game theory approach allows the analyst to develop a seemingly logical calculus of "relative support" for projects for each actor group, which can be expressed quantitatively, thus allowing it to mesh with other aspects of the decision analysis.

4) Regional Investment Analysis

A regional investment analysis of STOL/VTOL as a serious competitor for the transportation market must be tied closely to desired or resultant land use and spatial arrangements of growth of the region. As such:

a) The analysis results in the previous chapter imply that STOL/VTOL has certain "shock" values in developing more viable regional land use states, particularly in moving the system from declining or dormant land use-economic growth interrelationships.

b) Structuring the regional investment as a Markovian Decision Problem is a viable way to approximate these investment and growth state changes.

c) However, an assessment of transition and steady state probabilities is difficult. None the less, an assessment of these will be made in any informal, ad hoc analysis. Invoking a Markovian framework forces the analyst to develop the information for the system's computation in an exhaustive and current manner.

d) In the St. Louis case study, STOL/VTOL fares were used for analysis with the value of time at $10.00 per hour. The assumption of 50% operating subsidy coincident with the percentage operating subsidy for surface transit of the 1974 Mass Transportation Act was invoked to attempt comparison on an equitable philosophical basis for commuting activities. However, the issue of who pays, and the procedural sponsorship of such a subsidy, is an open one.

e) Regional surrogates for system value are extremely difficult to obtain. In light of the need for simple, computationally concise approaches which relate to gut issues of the region, such as environment vs. growth and economic health, the short cut value added and value matrices were used. However, any other, more complex regional analysis approach could be substituted for the reward matrix formulation.

Summary Conclusions - Need for Further Research

The following summary conclusions can be made, in light of the above:

a) Analytic techniques can be provided which yield insight into complex transportation evaluation and investment behavior. As stated in Chapter 1, and should be obvious, no "clean modelling" processes exist. Rather, the analytic structures must be built around the problem structure, reflecting its real world behavior as accurately as possible. Any analytic structure is subject to data and probabilistic input limitations. Throughout the analyses of the preceding chapters, the analyst is presumed to posess reasonably complete knowledge of his system's and/or agency's organizational procedures and related cost and performance data.

b) Emerging air technologies of vehicle and facility design, such as STOL/VTOL, have greatly improved chances of public and consumer acceptance if they are integrated into ongoing land use - transportation system activities. Adequate evaluation approaches are required, from an engineering and

planning point of view, to effect such implementation. The preceding chapters, particularly the case study, offer initial attempts at evaluation approaches which comprehensively integrate the air technology with the land use and transportation system.

c) A great deal of focus centered around fare, value of time, modal split preferences, and resulting subsidies apparently required. Major changes in life-style yielding increased value of time, such that it over-balances fare requirements documented herein, would yield more substantive travel demand, and acheive operations without the subsidy levels demonstrated. Pertinent to this, St. Louis, due to its low Net Residential Density, and level of development, may not be as appropriate a region to test this particular set of evaluation models as East, West or South Gulf Coast Regions, due to their well developed and highly intensive travel demand subareas. This comment is balanced by effects of air congestion likely to offset time advantage of STOL/VTOL in these regions, and the fact that St. Louis was chosen as a case study location due to the study team's exhaustive knowledge of its transportation options, travel demand behavior, regional goals and environment issues, and development performance history.

As such, the modelling inputs, performance, and conclusions are likely to be more accurate than if performed by the above team in one of the above regions. Most certainly, viable future research should include calibration of these model structures for other metropolitan locations possessing intense travel demand subareas.

d) The subsidy issues raised in this study directly interact with two extremes. At the technological extreme, can operating costs be reduced to where fares potentially drop to more competitive levels? Interactively with this, should the goal structure of the nation include subsidizing a newly operational technology which may have substantive regional, recreational, downtown and peripheral development benefits if linked appropriately and compatibly into the public works sector? What of the inefficient operator in the above subsidized environment? Should some operator performance specification vs. subsidy availability be developed to encourage technologically and operationally good use of STOL/VTOL to obtain the above regional benefits without incurring a great influx of inefficient operations? All of these questions are obvious areas of further research, and alternative policies and their quantitative impacts can be tested in the above models.

e) The above models have validity in studying other air transportation investments which have large regional-multi-regional impacts. Appropriate analytic problems for further research include use of the models in:

i) Analysis of a major regional air facility investment, such as a metropolitan airport location and design problem.

ii) Analysis of a regional commuter program which has a particular regional benefit focus, such as recreational travel. An example of such is the analysis of air commuter service associated with lake recreational and tourist commuting in the 5 state Ozarks Regional Commission Area, and its current lake recreational promotion program.

iii) Evaluation analysis efforts of state-wide Air Transportation Planning, implemented at the State DOT level, and integrated with FAA and DOT National Needs and Capital Improvement Programs analyses that are performed every 2 years.

iv) Development of a comprehensive methodological approach to evaluation of appropriate aeronautical manufacturing and airline industry expansion paths over the coming decades, in light of American life styles, energy and economic requirements, and

Federal perspectives with respect to them. Such a modelling approach could be used to develop compatible long range strategies and short range adjustment programs across the aircraft industry, the operator's activity and the government scientific, policy and regulatory sectors, thus yielding maximum benefit for the nation's air transport resources and users.

In ultimate conclusion, the research has raised some major philosophical, procedural, and analytic issues for further research, and demonstrated how analytic techniques can be used in justification and defense of technological investment strategy, and as tools for information gathering and isolation or synthesis of critical technical and non-technical concerns of relevance to the analyst in developing policy programs which are defensible and justifiably implementable.

BIBLIOGRAPHY

Airline View of STOL System Requirements, American Airlines, Inc. Feb. 1972, Final Report Prepared for D.O.T. Systems Development and Technology, DOT-OS-10075.

"The Airport in MicroCity: A Study of its Usage and Significance in Six Small Minnesota Communities", Center for the Study of Local Government, St. John's University, Collegeville, Minn, Sept. 1968.

"Alternative Policies for Effecting Intercity Energy use Reduction", Sokolsky, Saul, The Aerospace Corporation, El Segundo, CA, October, 1974.

"A Bibliography on Air Travel and Associated Ground Transportation," Janet D. Kiernan, Institute for Defense Analysis, Arlington, VA, June 1970.

"Dynamic Probabalistic Systems Volume I: Markov Models", Ronald A. Howard, Stanford University, John Wiley & Sons, Inc., New York, London, Sydney, Toronto, 1971.

"Dynamic Programming and Markov Processes", Ronald A. Howard, Mass. Institute of Technology, Technology Press of MIT & John Wiley and Sons, New York, London, 1960.

Frederick, John Hutchinson, Commercial Air Transportation, 4th ed., R.D. Irwin, 1955

Further Studies in Short Haul Air Transportation in the California Corridor, Richard S. Shevell, July 1974, Submitted to NASA-Ames Research Center, Contract No. NAS2-7199.

"The Impact of Scheduling Policy on Airline Operational Efficiency: A Preliminary Assessment," Barker, Benjamin J., Stanford University, July 1974.

Inter-Metropolitan STOL Evaluation: Final Report (Phase X); Development Engineering, Report #50, January 1970, American Airlines.

Locklin, Dr. Philip, Economics of Transportation, Richard D. Irwin, Inc., Homewood, Illinois.

"Major Commercial Airport Location: A Methodology for the Evaluation of Potential Sites", Michael S. Bambiger, Hugo L. Vandersypen, The Transportation Center, Northwestern University, Evanston, Illinois, August 1969.

"N-Person Game Theory Concepts and Applications", Anatol Rapaport, University of Michigan Press, Ann Arbor, 1970.

Official Airline Guide: North America Edition, March 1, 1975, Volume I, No. 11, Reuben H. Donnelley Publication.

A Perspective in the Assessment of Large-Scale Technology: The Case of the STOL Aircraft Transport System, A Progress Report, November 1971, by Todd R. LaPorte, Bayard Latron, John Forester, N. Mayer and Daniel Metlay, Institute of Governmental Studies, University of California, Berkeley, for Ames Research Center, NASA.

"Principles of Engineering Economy", 5th Edition, Eugene L. Grant, W. Grant Ireson, Ronald Press Company, New York, 1970.

"Regional Airport Study, Joplin Missouri, Volume 1,2" Isbill Associates, Inc., Denver, Colorado, (Feb. 1971) for Ozarks Regional Commission.

St. Louis Region 1971 Annual Transportation Report, East-West Gateway Coordinating Council, March 1972, 720 Olive Street, Suite 2110, St. Louis, MO 63101

Short-Haul Airline System Impact on Intercity Energy Use - Final Report, S. Sokolsky, Air Transportation Group, May 31, 1974, Prepared for Ames Research Center, National Aeronautics and Space Administration, Moffett Field, California, Contract No. NAS2-6473.

"South Dakota State Airport System Plan - Final Report", Daniel, Mann, Johnson, & Mendenhall and Associates, Los Angeles, CA, December 30, 1970 for South DAkota State Planning Agency.

"STOL Aircraft in Intraurban Travel", McDonnell Aircraft Company, McDonnell Douglas Corporation, St. Louis, MO, June 1968.

Study of Aircraft in Intraurban Transportation Systems San Francisco Bay Area, prepared by the Boeing Company for Ames Research Center, NASA, Washington, D.C., March 1972, NASA CR-2006.

"Study of Aircraft in Intraurban Transportation Systems San Francisco Bay Area", The Boeing Company, Seattle Washington, September 1971, NASA Contract No. NAS2-5969.

"Study of Aircraft in Intraurban Transportation Systems San Francisco Bay Area", Boeing Company, Seattle, Washington, for National Aeronautics and Space Administration, NASA CR-114347, September 1971.

Study of Aircraft in Intraurban Transportation Systems, by E.G. Stout, prepared by Lockheed-California Company for Ames Research Center, NASA, Washington, D.C., March 1972, NASA CR-1991.

"Study of an Intraurban Travel Demand Model Incorporating Commuter Preference Variables", Holligan, Paul E., Coote, Malcolm A., Rushmer, Charles R., Fanning, Michael L., Boeing Company, Seattle, Washington, December 1971, NASA Contract NAS2-5969.

Study of Quiet Turbofan STOL Aircraft for Short-Haul Transportation - Final Report, Volume III Airports, June 1973, Prepared under Contract No. NAS2-6994 for Advanced Concepts and Missions Division NASA, Moffett Field, California 94035 by Douglas Aircraft Company, Long Beach, CA.

"Study of Traffic Flow on a Restricted Facility Interim Report - Phase 1", Department of Civil Engineering, University of Maryland, Everett C. Carter, Project Director, Sulur P. Palaneswamy, Principle investigator, June 1973.

"Technical and Economic Evaluation of Aircraft for Intercity Short Haul Transportation", Volumes I, II, III, McDonnell Aircraft Corporation, St. Louis, MO, April 1966, FAA Contract No. FA65WA-1246.

"Toward Environmental Benefit/Cost Analysis , Measurement and Methodology," DeVoy, Robert S., Haefner, Lonnie E., March 1972.

"Western Region Short-Haul Air Transportation Program, Definition Phase Report, Volume I, Demonstration Program Plan," E.R. Hinz, Director, Air Transportation Program, The Aerospace Corporation, July 1970.

"Western Region Short-Haul Air Transportation Program, Definition Phase Report, Volume II, Technical Report", Air Transportation Program Office, The Aerospace Corporation, July 1970.

PROFESSIONAL INTERVIEWS

Roland C. Marquart	Manager, Transportation Services, St. Louis Regional Commerce and Growth Association, Ten Broadway, St. Louis, Missouri 63102
Dave Wuenscher Dick Odebrecht	Real Estate Research Corporation 230 S. Bemiston Clayton, MO
Mr. J.R. Smith	District Supervisor Western Division, Greyhound Lines, Inc.,Broadway and Delmar Streets, St. Louis, MO 63102
Mr. George Marks	Sverdrup & Parcel, Inc. 800 N. 12th Blvd. St. Louis, MO 63101
Mr. Paul H. Orr	District Sales Manager, National Railroad Passenger Corporation, Amtrak, 818 Olive Street, St. Louis, MO 63101
Mrs. Johnson	Air Commuter Center Lambert Field St. Louis, MO
Mr. Albert A. Michenfelder Jr.	130 S. Bemiston Clayton, MO

APPENDIX A

INPUTS FOR R&D EVALUATION

NOTATIONS

E - the experiment number

Z - the outcome number

A - the action number

S - the state number

P(Z E,S) - the conditional probability of outcome z occurring, given that experiment E is performed and state S is the true state of the system

U - the utility of the combination of E,Z,A and S.

E	Z	A	S	P(Z|E,S)	U
1	1	1	1	.55	10
1	1	2	1	.55	25
1	1	3	1	.55	40
1	1	1	2	.50	5
1	1	2	2	.50	20
1	1	3	2	.50	35
1	1	1	3	.45	2
1	1	2	3	.45	30
1	1	3	3	.45	50
1	1	1	4	.35	2
1	1	2	4	.35	25
1	1	3	4	.35	60
1	2	1	1	.30	12
1	2	2	1	.30	30
1	2	3	1	.30	40
1	2	1	2	.25	8
1	2	2	2	.25	30
1	2	3	2	.25	45
1	2	1	3	.30	5
1	2	2	3	.30	50
1	2	3	3	.30	45
1	2	1	4	.35	2
1	2	2	4	.35	40
1	2	3	4	.35	60

E	Z	A	S	P(Z∣E,S)	U
1	3	1	1	.15	45
1	3	2	1	.15	20
1	3	3	1	.15	5
1	3	1	2	.25	55
1	3	2	2	.25	20
1	3	3	2	.25	5
1	3	1	3	.25	50
1	3	2	3	.25	30
1	3	3	3	.25	5
1	3	1	4	.30	45
1	3	2	4	.30	40
1	3	3	4	.30	30
01	1	1	1	1	15
01	1	2	1	1	30
01	1	3	1	1	1
01	1	1	2	1	20
01	1	2	2	1	15
01	1	3	2	1	1
01	1	1	3	1	10
01	1	2	3	1	25
01	1	3	3	1	1
01	1	1	4	1	5
01	1	2	4	1	30
01	1	3	4	1	1

E	Z	A	S	P(Z|E,S)	U
01	2	1	1	.01	1
01	2	2	1	.01	1
01	2	3	1	.01	1
01	2	1	2	.01	1
01	2	2	2	.01	1
01	2	3	2	.01	1
01	2	1	3	.01	1
01	2	2	3	.01	1
01	2	3	3	.01	1
01	2	1	4	.01	1
01	2	2	4	.01	1
01	2	3	4	.01	1
01	3	1	1	.01	1
01	3	2	1	.01	1
01	3	3	1	.01	1
01	3	1	2	.01	1
01	3	2	2	.01	1
01	3	3	2	.01	1
01	3	1	3	.01	1
01	3	2	3	.01	1
01	3	3	3	.01	1
01	3	1	4	.01	1
01	3	2	4	.01	1
01	3	3	4	.01	1

E	Z	A	S	P(Z|E,S)	U
2	1	1	1	.45	15
2	1	2	1	.45	35
2	1	3	1	.45	50
2	1	1	2	.4	20
2	1	2	2	.4	30
2	1	3	2	.4	40
2	1	1	3	.4	30
2	1	2	3	.4	30
2	1	3	3	.4	35
2	1	1	4	.5	35
2	1	2	4	.5	20
2	1	3	4	.5	15
2	2	1	1	.3	20
2	2	2	1	.3	30
2	2	3	1	.3	40
2	2	1	2	.4	30
2	2	2	2	.4	30
2	2	3	2	.4	35
2	2	1	3	.3	35
2	2	2	3	.3	20
2	2	3	3	.3	15
2	2	1	4	.25	40
2	2	2	4	.25	25
2	2	3	4	.25	20

E	Z	A	S	P(Z|E,S)	U
2	3	1	1	.25	35
2	3	2	1	.25	20
2	3	3	1	.25	15
2	3	1	2	.2	40
2	3	2	2	.2	25
2	3	3	2	.2	20
2	3	1	3	.3	45
2	3	2	3	.3	30
2	3	3	3	.3	25
2	3	1	4	.25	50
2	3	2	4	.25	35
2	3	3	4	.25	30
02	1	1	1	1	45
02	1	2	1	1	10
02	1	3	1	1	1
02	1	1	2	1	35
02	1	2	2	1	15
02	1	3	2	1	1
02	1	1	3	1	30
02	1	2	3	1	20
02	1	3	3	1	1
02	1	1	4	1	25
02	1	2	4	1	25
02	1	3	4	1	1

E	Z	A	S	P(Z∣E,S)	U
02	2	1	1	.01	1
02	2	2	1	.01	1
02	2	3	1	.01	1
02	2	1	2	.01	1
02	2	2	2	.01	1
02	2	3	2	.01	1
02	2	1	3	.01	1
02	2	2	3	.01	1
02	2	3	3	.01	1
02	2	1	4	.01	1
02	2	2	4	.01	1
02	2	3	4	.01	1
02	3	1	1	.01	1
02	3	2	1	.01	1
02	3	3	1	.01	1
02	3	1	2	.01	1
02	3	2	2	.01	1
02	3	3	2	.01	1
02	3	1	3	.01	1
02	3	2	3	.01	1
02	3	3	3	.01	1
02	3	1	4	.01	1
02	3	2	4	.01	1
02	3	3	4	.01	1

E	Z	A	S	P(Z|E,S)	U
3	1	1	1	.4	15
3	1	2	1	.4	25
3	1	3	1	.4	35
3	1	1	2	.35	20
3	1	2	2	.35	30
3	1	3	2	.35	35
3	1	1	3	.3	25
3	1	2	3	.3	25
3	1	3	3	.3	30
3	1	1	4	.25	25
3	1	2	4	.25	25
3	1	3	4	.25	30
3	2	1	1	.35	25
3	2	2	1	.35	30
3	2	3	1	.35	20
3	2	1	2	.30	30
3	2	2	2	.30	30
3	2	3	2	.30	20
3	2	1	3	.3	35
3	2	2	3	.3	30
3	2	3	3	.3	25
3	2	1	4	.35	40
3	2	2	4	.35	35
3	2	3	4	.35	25

E	Z	A	S	P(Z|E,S)	U
3	3	1	1	.25	45
3	3	2	1	.25	35
3	3	3	1	.25	35
3	3	1	2	.35	40
3	3	2	2	.35	35
3	3	3	2	.35	30
3	3	1	3	.4	45
3	3	2	3	.4	25
3	3	3	3	.4	30
3	3	1	4	.4	50
3	3	2	4	.4	45
3	3	3	4	.4	20
03	1	1	1	1	55
03	1	2	1	1	20
03	1	3	1	1	1
03	1	1	2	1	60
03	1	2	2	1	25
03	1	3	2	1	1
03	1	1	3	1	65
03	1	2	3	1	30
03	1	3	3	1	1
03	1	1	4	1	55
03	1	2	4	1	35
03	1	3	4	1	1

E	Z	A	S	P(Z|E,S)	U
03	2	1	1	.01	1
03	2	2	1	.01	1
03	2	3	1	.01	1
03	2	1	2	.01	1
03	2	2	2	.01	1
03	2	3	2	.01	1
03	2	1	3	.01	1
03	2	2	3	.01	1
03	2	3	3	.01	1
03	2	1	4	.01	1
03	2	2	4	.01	1
03	2	3	4	.01	1
03	3	1	1	.01	1
03	3	2	1	.01	1
03	3	3	1	.01	1
03	3	1	2	.01	1
03	3	2	2	.01	1
03	3	3	2	.01	1
03	3	1	3	.01	1
03	3	2	3	.01	1
03	3	3	3	.01	1
03	3	1	4	.01	1
03	3	2	4	.01	1
03	3	3	4	.01	1

APPENDIX B

MATHEMATICAL ASPECTS OF BAYESIAN DECISION THEORY

APPENDIX B

MATHEMATICAL PROPERTIES OF BAYESIAN DECISION THEORY

The purpose of this chapter is to formally present the properties of Bayesian Decision Theory as an evaluation tool.

The basic structure of a Bayesian Decision problem is imposed through the following:

1.) $\theta_i \in \theta$, a series of possible conditions of the system under study, defined as "states of the world" that could occur.

2.) $e_k \in E$, a group of experiments, of which one or several could be run, in order to yield more information about the true state of the world θ_i, above.

3.) $z_j \in Z$, all possible outcomes associated with an experiment.

4.) $a_\ell \in A$, a set of alternatives, one or more of which may be chosen in a decision situation.

5.) $U(e, z, a, \theta)$, a utility, which is a scalar measure representing the relative value to the decision-maker of a particular combination of an experiment, an outcome, choosing a particular alternative and having a particular state of the world obtain.

In essence, the evaluation scheme may be looked upon as a game, played over a decision tree, as shown in Figure 49, with the following components:

1.) Decision to perform particular experiment.

2.) Experiment, prediction, outcome.

3.) Decision to choose a particular alternative.

4.) Realized utility, a random variable due to θ.

Note a decision is made to employ a particular experiment e_k, which results in an outcome z_j that is a random variable. On the basis of the added knowledge about the state of the world and an original assessment, an alternative a_ℓ is chosen, and is executed in the face of θ_i, the resulting state of the world, which is also a random variable. The above random outcomes and deterministic choices result in a utility accruing to the decision-maker.

A. Stochastic Inputs in Bayesian Decision Theory

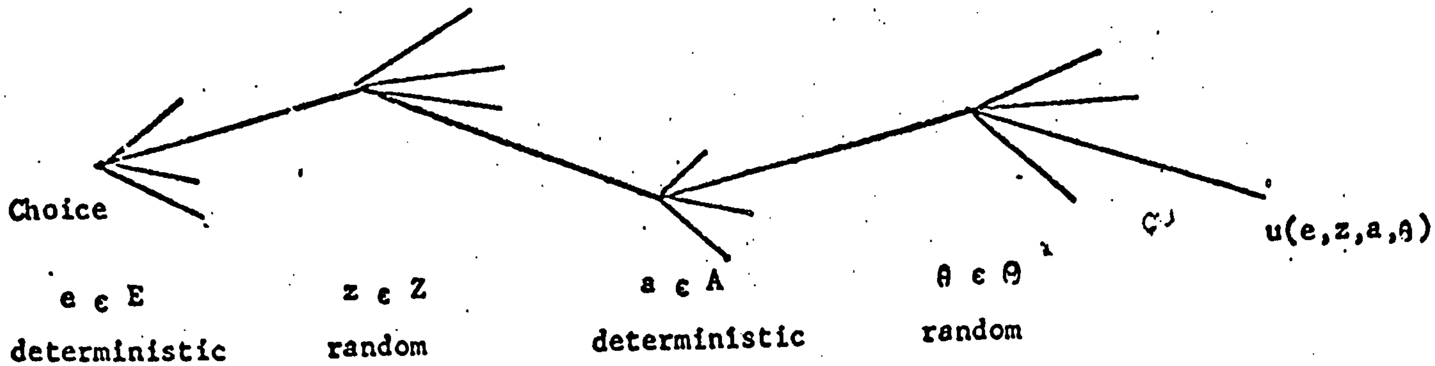
The following information on stochastic aspects of the problem is used in the evaluation:

1.) $P'(\theta_i)$ = The prior, or marginal measure on the probability of a state of the world i. This measure is assessed on the basis of a subjective knowledge, or "feel" for the problem, and is prior to the experimentation phase.

2.) $P(z_j|e_k,\theta_i)$ = The conditional probability of an outcome j from experiment e_k, given the true state of the world is i. This is also assessed prior to undertaking the experimentation.

3.) The joint probability, $P(\theta_i,z|e)$, which = $P'(\theta_i) \times P(z_j|e_k,\theta_i)$, and is the probability of occurrence of a particular combination of θ_i and z_j with experiment e_k.

ASPECTS OF THE BAYESIAN DECISION PROCESS



B-1

Figure 49

4.) $P(z_j|e_k) = \sum_i P(\theta_i, z_j|e_k)$, which is the marginal probability of an outcome z_j using experiment e_k, over all states of the world.

5.) $P''(\theta_i|z_j,e_k)$ = The revised or posterior probability of state of the world i, after obtaining outcome z_j from experiment e_k. This is obtained through the use of Bayes' Rule, where $P''(\theta_i|z_j,e_k) = \dfrac{P(\theta_i|z_j,e_k)}{\sum_i P(\theta_i,z_j|e_k)}$.

B. <u>Information Required for Beginning Computation</u>

Three basic methods exist for fulfilling appropriate computations; based on the possible stochastic information, they are:

1.) Joint measures on $\theta \times Z$ are given, and the marginals and conditional for θ and Z are computed from it, resulting in information to subsequently compute the posterior probabilities.

2.) Marginal, or prior measures for all θ are given, and a conditional on Z for every θ_i in θ is likewise given. The joint measures, marginals on Z, and posteriors on θ are computed.

3.) Marginals on Z are given, and posterior probabilities on θ are given. The joints are subsequently computed, and ultimately the priors on θ and conditionals on Z.

C. <u>Alternative Evaluation Schemes</u>

Two alternative types of evaluation may be developed in Bayesian Decision Theory, termed the <u>extensive</u> form, and the <u>normal</u> form. These

77

will be described separately, and subsequently discussed. Description will make use of the decision tree in Figure ~~50~~.[1,2,3]

B-2

1. Extensive Form

Referring to the decision tree in Figure 50, the following steps are taken.

1.) The expected utility given the selection of any alternative a_ℓ (presuming a particular experiment and outcome precedes selection of this alternative is):

$$U^*(e_k,z_j,a_\ell) = \sum_i (U(e_k,z_j,a_\ell,\theta_i)) \times (P''(\theta_i|z_j,e_k)$$

in Figure 36, referring to point D, for (e_1,z_1,a_1), $U^*(e_1,z_1,a_1) = 94(.891) + 7(.109) = 85$.

2.) The optimal alternative for each experimental outcome is then selected:

$$U^*(e_k,z_j) = \max_{a_\ell} (U^*(e_k,z_j,a_\ell)).$$

There is one such value for each z edge of the decision tree, and is recorded at point C in Figure 36.

3.) The expected value of each experiment is now computed and placed at point B on the tree.

---

[1]Howard Raiffa, and Robert Schlaifer, op. cit., pp. 1-22.

[2]Morris H. DeGroot, op. cit., pp. 69-155.

[3]E. K. Morlok, and H. Haack, "Discussion Topic 1, Statistical Decision Theory," class notes from D01-Transportation Systems, Evaluation, Winter, 1969.

DECISION TREE

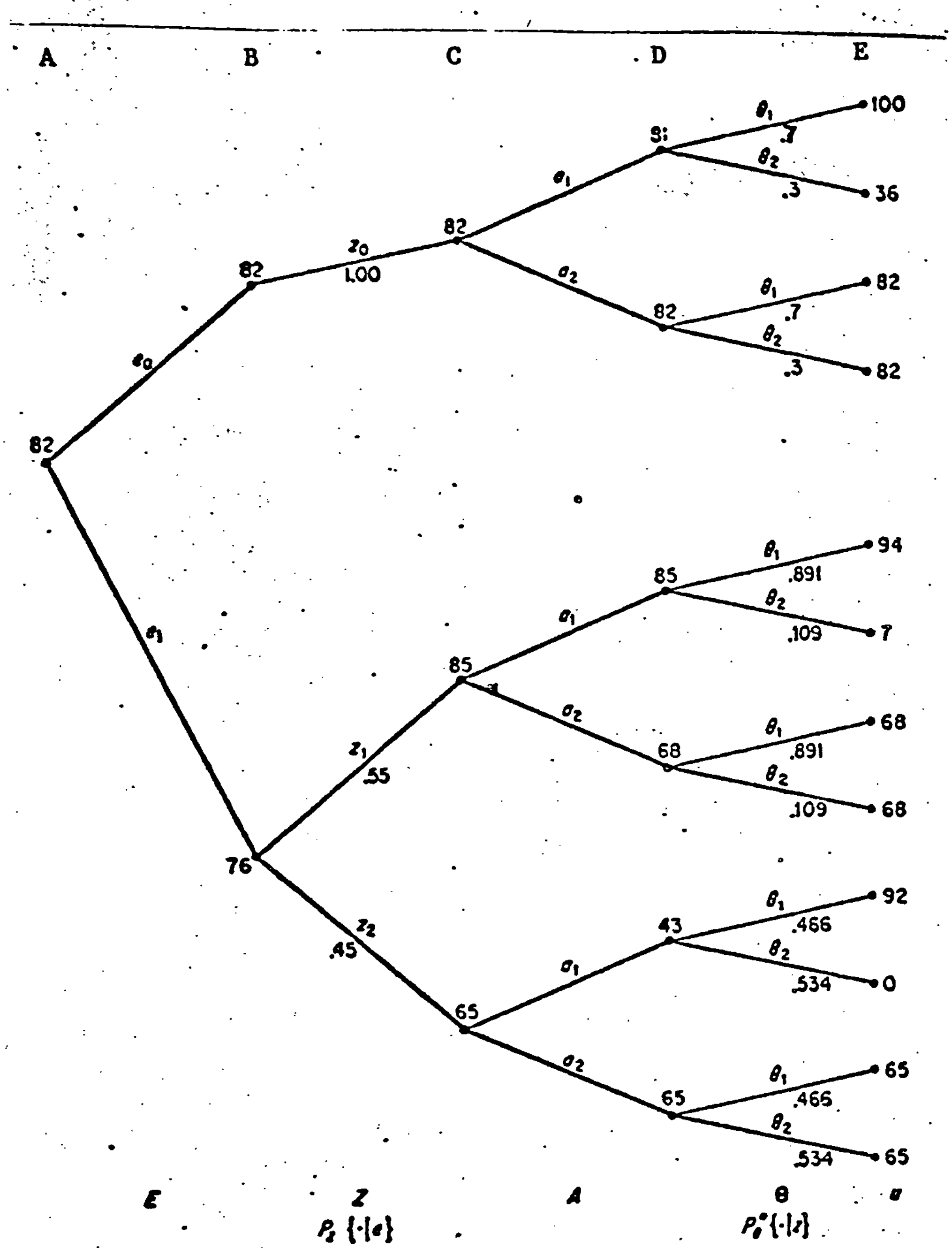


Figure 50

$$U^*(e_k) = \sum_j (U^*(e_k, z_j)) \cdot P(z_j | e_k) \quad .$$

4.) The optimal experiment is thus $U^* = \max_k U^*(e_k)$, the maximum expected value corresponds to point A in the tree.

2. Normal Form Analysis

To make use of the normal form of analysis, we introduce the concept of a decision rule, which associates an optimal alternative a with each possible outcome z. In the normal form, every decision rule for experiment e_k is considered, and the optimum rule is selected. Each experiment is then evaluated, and the best e is selected.

As an example of decision rules, returning to Figure 50:

1.) The optimal decision rule d^0 for experiment e_1 is:

$$d_{11} \text{ where } d_{11}(z_1) = a_1 \text{ and } d_{11}(z_2) = a_2 \quad .$$

2.) Non-optimal decision rules for experiment e_1 are:

$$d_{12} \text{ where } d_{12}(z_1) = a_2 \text{ and } d_{12}(z_2) = a_1$$

$$d_{13} \text{ where } d_{13}(z_1) = a_1 \text{ and } d_{13}(z_2) = a_1$$

$$d_{14} \text{ where } d_{14}(z_1) = a_2 \text{ and } d_{14}(z_2) = a_2 \quad .$$

A formalized procedure for finding an optimum e and $d(z_j)$ is as follows:

1.) Assume that e and d are given and that we hold θ fixed.

2.) Take the expectation of $U(e,\tilde{z},d(\tilde{z}),\theta)$ with respect to the conditional measure $P_{z/e,\theta}$.

3.) The result is

$$U_*(e,d,\theta) \equiv E_{z/e,\theta} U(e,\tilde{z},d(\tilde{z}),\theta) \quad .$$

Call this the <u>conditional</u> utility of (e,d) <u>for the given state</u> θ.

4.) Now expect over $\tilde{\theta}$ with respect to the unconditional measure, P'_θ, to obtain:

$$U_*(e,d) = E'_\theta U_*(e,d,\tilde{\theta}) \quad .$$

Call this the <u>unconditional</u> utility of (e,d).

5.) Next, given any particular experiment e, choose the decision rule d whose expected utility is greatest; the utility of any experiment being:

$$U_*(e) \equiv \max_d U_*(e,d)$$

6.) Compute the utility of every experiment e in E. Then choose the experiment with the greatest utility.

$$U_* \equiv \max_e U_*(e) = \max_e \max_d E'_\theta E_{z/e,\theta} U(e,\tilde{z},d(\tilde{z}),\tilde{\theta}) \quad .$$

3. Discussion of Normal and Extensive Forms

A comparison of the two forms yields some interesting information. Of primary importance is that the extensive and normal form both yield identical answers as to choice of experiment and action. Ultimately, both require the same information, however, the normal form allows one to put off subjective analysis of $P'(\theta_i)$ until the end of the evaluation, and at the outset, makes use of $P(z_j|e_k,\theta_i)$, which is a measure that can frequently be assigned from past experience. Alternatively, where it appears best to introduce subjective judgment early in the process, the extensive form can be used.

D. Sequential Sampling

A final characteristic of Bayesian Decision Theory is its ability to allow further information about the problem to be generated, if deemed valuable, prior to action. Such a concept is termed sequential sampling, or sequential experimentation. Its features bear some resemblance to the optimal path problem in network analysis.

As stated before, the analyst has the option of performing one of several experiments, and these experiments can be replicated at any subsequent stage in the process. The assumption is made that each experiment has the same fixed monetary or opportunity cost, which equals C. Further, N stages exist at the end of which an alternative a must be selected. At any stage the decision-maker has the option of experimenting further, or to use the alternative specified by the decision rule corresponding to the present experimental outcome.[1] This process may be conceptualized as

[1] Morris H. DeGroot, op. cit., pp. 267-287 and pp. 429-433.

in Figure 51, which shows a network of possible choices throughout the N stages.

The theorem underlying the selection of the optimal process over N stages is as follows:[1] For j = 1,...,N - 1, suppose experiment $E_1 = e, \ldots, E_j = e$ have been run. If $U_j^* \leq [(U_{j+1}^*) - C]$, the additional optimal experiment shall be run at stage j + 1. If the inequalities are reversed, the action prescribed at j should be taken. U_{j+1}^* is computed using the revised probabilities from j as prior probabilities in j + 1. At stage N, the action presdribed must be taken.

Looking at Figure 51, one sees that the optimal experiment is selected at stage 1, and by use of the above rule, the optimal choice of action or further experimentation is traced through each succeeding stage, with the network terminating in the action node, at the latest, by stage N.

---

[1]Paraphrased in part from DeGroot, op. cit., p. 280.

BACKWARDS INDUCTION IN SEQUENTIAL SAMPLING

N = 4

e = 3

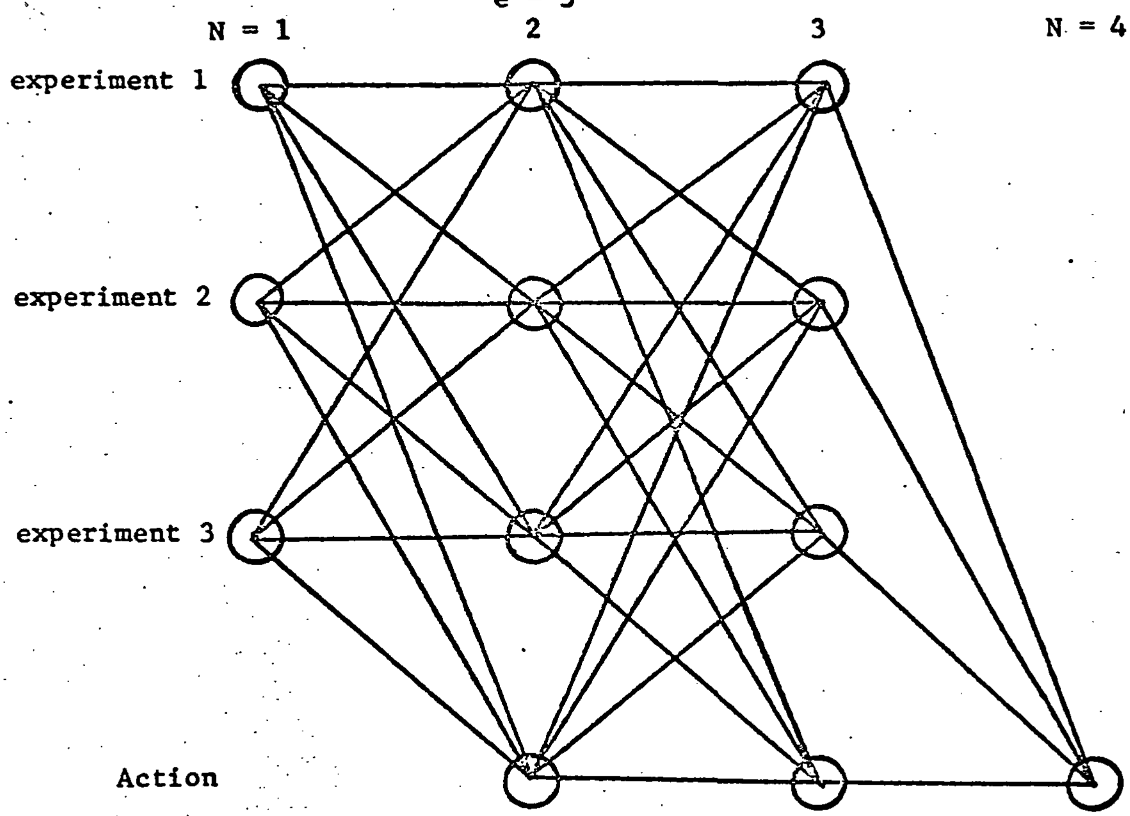


Figure 51

APPENDIX C

MATHEMATICAL ASPECTS OF MARKOVIAN DECISION THEORY

APPENDIX C-1

MARKOVIAN DECISION THEORY

A. Expected Reward of a Policy

The expected reward $v_i(n)$ from a set of staged decisions (policy), given a starting point (i) is defined by the recurrence relationship

$$v_i(n) = \sum_{j=1}^{N} p_{ij}\left(r_{ij} + v_j(n-1)\right) \qquad i = 1, 2, ..N, \quad n = 1, 2, ...$$

By defining q_i, the expected reward from the next stage transition, given the starting state i

$$q_i = \sum_{j=1}^{N} p_{ij}r_{ij} \qquad i = 1, 2, \ldots N$$

the recurrence relationship can be written in the form

$$v_i(n) = q_i + \sum_{j=1}^{N} p_{ij}v_j(n-1) \qquad i = 1, 2, \ldots N, \; n = 1, 2, \ldots$$

As an example, suppose our problem contained two states, with matrices

$$R = \begin{bmatrix} 9 & 3 \\ 3 & -7 \end{bmatrix} \qquad P = \begin{bmatrix} .5 & .5 \\ .4 & .6 \end{bmatrix}$$

Then, after computing

$$q = \begin{bmatrix} 6 \\ -3 \end{bmatrix}$$ the recurrence relationship can be used to construct the values in the following table:

TOTAL EXPECTED REWARD AS A FUNCTION OF STATE
AND NUMBER OF STAGES REMAINING

n =	0	1	2	3	4	5
$v_1(n)$	0	6	7.5	8.55	9.555	10.5555
$v_2(n)$	0	-3	-2.4	-1.44	-0.444	0.5556

B. Gain of an Ergodic Process

The gain (g) of an ergodic process can be found from

$$g = \sum_{i=1}^{N} \pi_i q_i$$

where q_i is the expected immediate return in state i and π_i is the steady state probability of state i. The gain can be visualized as the return per transition of the process.

C. The Policy Iteration Method

Expected total return is defined as

$$v_i(n) = q_i + \sum_{j=1}^{N} p_{ij} v_j(n-1) \qquad i = 1, 2, .. N \qquad n = 1, 2, ...$$

As n increases, $v_i(n)$ asymptotically approaches the line

$$v_i(n) = ng + v_i$$

for the ergodic process (where g is the gain and v_i is the axis intercept). If the system is run for a large number of stages one can use

$\sum_{j=1}^{N} p_{ij} = 1$ to develop the relationship

$$g + v_i = q_i + \sum_{j=1}^{N} p_{ij} v_j \qquad i = 1, 2, ...N$$

which is a set of N simultaneous linear equations with N + 1 unknowns (N v_i's and one g). Setting $v_N = 0$ allows solution of the system for g, the expected (relative) gain of a policy. By comparing gains for the set of possible policies, the optimal policy can be determined.

If an optimal policy exists up to stage n, the best alternative in the ith state at stage n+1 can be found by maximizing the function

$$q_i{}^k + \sum_{j=1}^{N} p_{ij} v_j{}^k(n)$$

over all alternatives (k) in the ith state. Using the results obtained in the last section for large n, substitute

$$v_i(n) = ng + v_i$$

and obtain the test quantity

$$q_i{}^k + \sum_{j=1}^{N} p_{ij}{}^k v_j$$ with respect to the alternatives in the ith state. In summary: for each state i, find the alternative k that maximizes the test quantity using the relative values determined under the old policy. The alternative k now becomes d_i, the decision in the ith state. A new policy has been determined when this procedure has been performed for every state. The iteration cycle is as follows:

VALUE-DETERMINATION OPERATION

Use p_{ij} and q_i for a given policy to solve

$$g + v_i = q_i + \sum_{j=1}^{N} p_{ij} v_j \qquad i = 1, 2, \ldots N$$

for all relative values v_i and g (by setting $v_N = 0$).

POLICY IMPROVEMENT ROUTINE

For each state i, find the alternative k* that maximizes

$$q_i{}^k + \sum_{j+1}^{N} p_{ij}{}^k v_j$$

using the relative values v_i of the previous policy. Then k* becomes the new decision in the ith state, $q_i{}^{k*}$ becomes q_i, and $p_{ij}{}^{k*}$ becomes p_{ij}.

The process can begin in either of the boxes. If value determination is selected as the starting point, an initial policy must be selected. If policy improvement is to start, then a starting set of values is necessary. If nothing else is *a priori* better, it is convenient to start in policy improvement with all $v_i = 0$. The optimal policy is reached when two successive iterations are identical in policy chosen. In our examples above, we are given the following data:

State	Alternative	Transition Probabilities		Rewards		Expected Immediate Return
i	k	p_{i1}^k	p_{i2}^k	r_{i1}^k	r_{i2}^k	q_i^k
1	1	.5	.5	9	3	6
	2	.8	.2	4	4	4
2	1	.4	.6	3	-7	-3
	2	.7	.3	1	-19	-5

Step 1: Set $v_1 = v_2 = 0$ and enter policy improvement routine

Step 2: It chooses maximum immediate returns, giving

$$d = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \qquad P = \begin{bmatrix} .5 & .5 \\ .4 & .6 \end{bmatrix} \qquad q = \begin{bmatrix} 6 \\ -3 \end{bmatrix}$$

Step 3: Entering the value determination routine:

$$g + v_1 = 6 + .5v_1 + .5v_2 \qquad \text{and}$$

$$g + v_2 = -3 + .4v_1 + .6v_2 \qquad \text{By setting } v_2 = 0 \text{ we solve and obtain}$$

$$g = 1 \qquad v_1 = 10 \qquad v_2 = 0.$$

Step 4 Applying the policy improvement routine:

State i	Alternative k	Test Quantity $q_i^k + \sum_{j=1}^{2} p_{ij}^k v_j$
1	1	$6 + .5(10) + .5(0) = 11$
	2	$4 + .8(10) + .2(0) = 12*$
2	1	$-3 + .4(10) + .6(0) = 1$
	2	$-5 + .7(10) + .3(0) = 2*$

yields

$$d = \begin{bmatrix} 2 \\ 2 \end{bmatrix} \qquad p = \begin{bmatrix} .8 & .2 \\ .7 & .3 \end{bmatrix} \qquad q = \begin{bmatrix} 4 \\ -5 \end{bmatrix}$$

Step 5: Repeating the process:

$$g + v_1 = 4 + .8v_1 + .2v_2$$

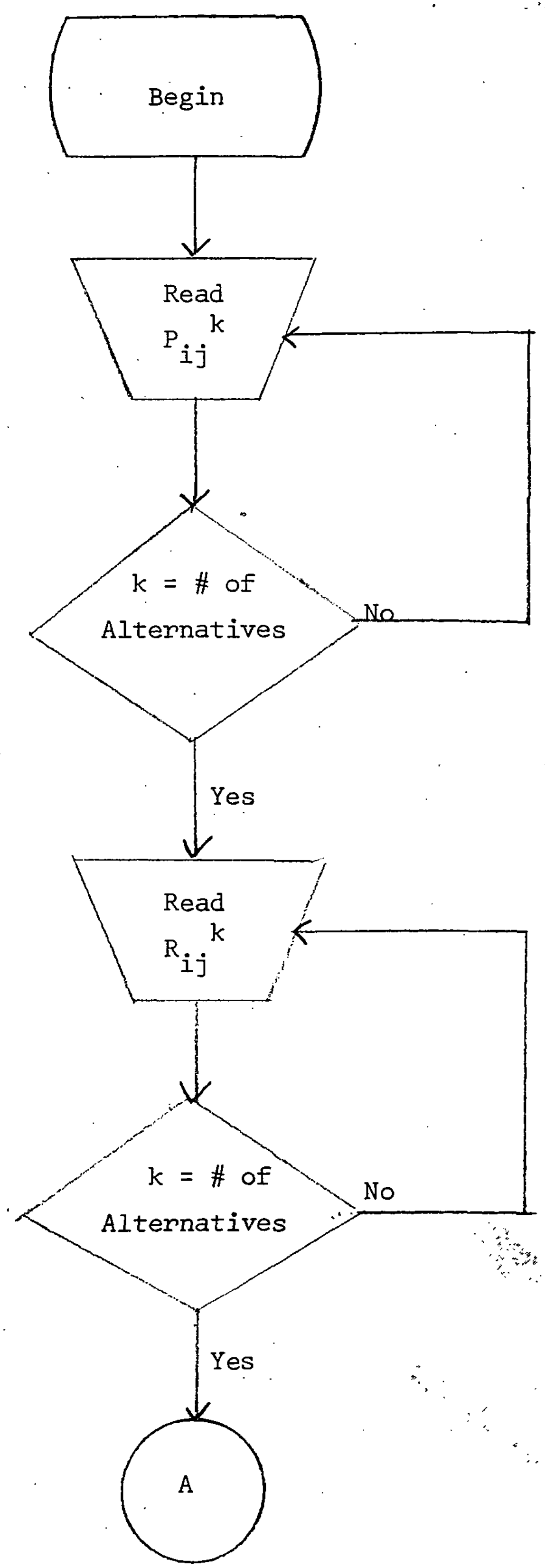
$$g + v_2 = -5 + .7v_1 + .3v_2$$

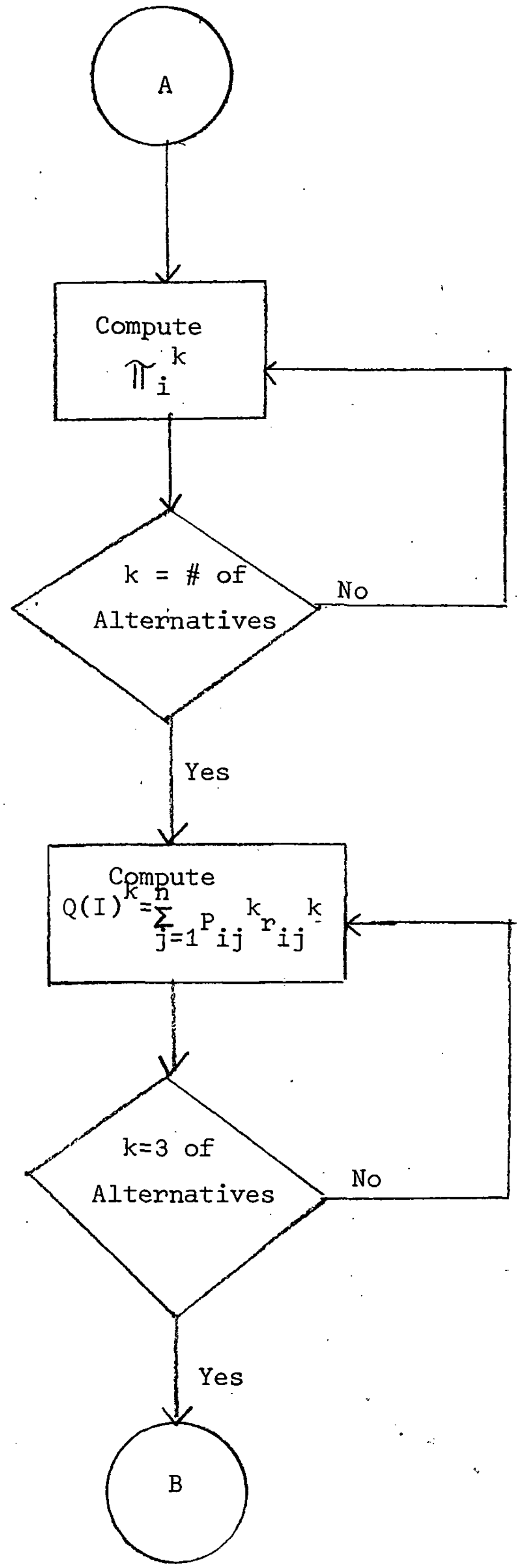
yielding $v_2 = 0$ $\qquad g = 2$ $\qquad v_1 = 10$

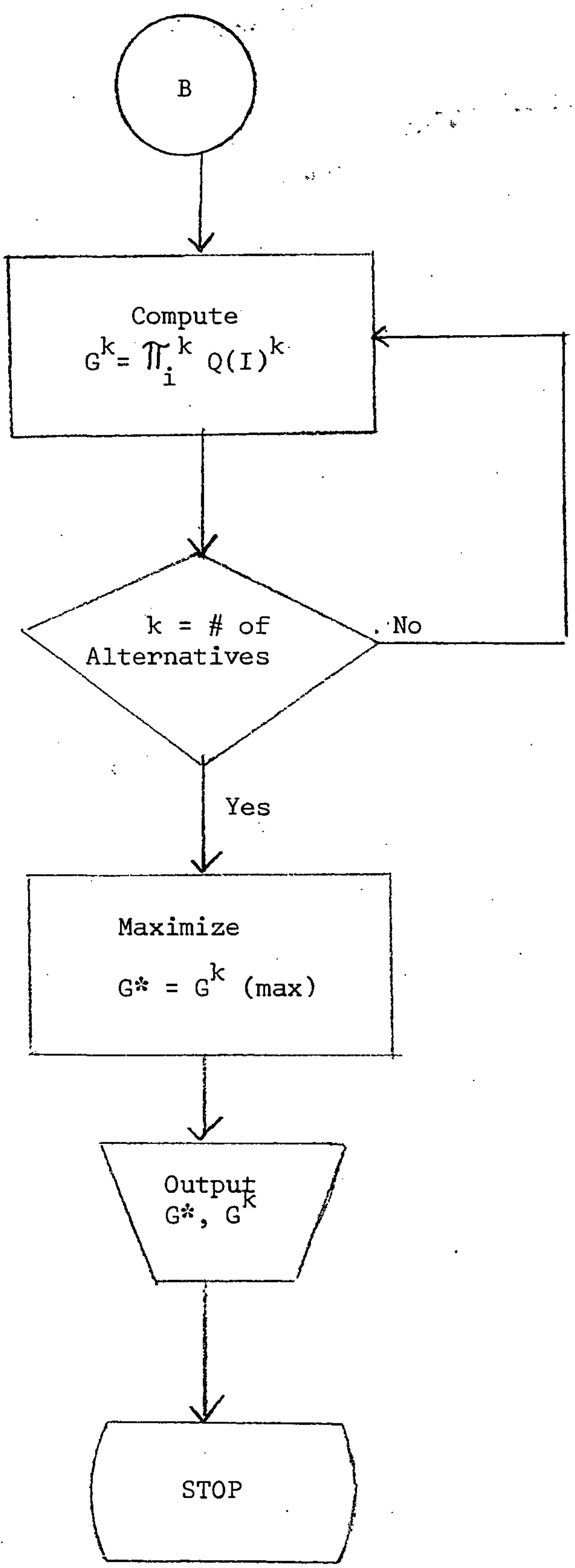
Step 6: As one can see, the computations will be identical, and will yield the same results. Then we have reached two successive identical policies, implying that this is the optimal policy:

$$d = \begin{bmatrix} 2 \\ 2 \end{bmatrix}$$

C-2 Computation of π_i and Q_i




A
Compute
π_i^k
k = # of
Alternatives
No
Yes
Compute
$Q(I)^k = \sum_{j=1}^{n} P_{ij}^k r_{ij}^k$
k=3 of
Alternatives
No
Yes
B


B
Compute
$G^k = \prod_i^k Q(I)^k$
k = # of
Alternatives
No
Yes
Maximize
$G^* = G^k$ (max)
Output
G^*, G^k
STOP

APPENDIX D

DIRECT OPERATING COSTS INPUTS - RURAL COMMUTER AIRLINES

APPENDIX D

DIRECT OPERATING COSTS INPUTS - RURAL COMMUTER AIRLINES

1. Crew pay: pilots required per flight

a. Commuter region	2 men	$10.00 per hour
b. Remote region	1 man	$10.00 per hour

2. Aircraft purchase

a. Commuter region - three, ten passenger aircraft

Capital Cost	$1,410,000
Spares	$350,000
Introduction Cost	$100,000
	$1,860,000

b. Remote region - seven, four passenger aircraft

Capital Cost	$560,000
Spares	$140,000
Introduction Cost	$50,000
	$750,000

3. Insurance: 2% per year of initial plane price

4. Fuel Costs - $.20/gal.

a. Commuter region - typical aircraft Beechcraft 18

Fuel Consumption Rate	50 ga./hr.
Cruise Speed	225 mph

b. Remote region - typical aircraft Cherokee 6

Fuel Consumption Rate	16 gal./hr.
Cruise Speed	170 mph

5. Maintenance Cost = 30% (annual plane cost)

   Maintenance plus labor cost = 1.8 (maintenance cost)

APPENDIX E

EXAMPLE OF TRIP TOTALS AND HOURLY DISTRIBUTION OF A TYPICAL CITY IN THE MIDWEST STUDY REGION

APPENDIX E DAILY PASSENGER VOLUME ST. LOUIS TO AND FROM KANSAS CITY

CITY # = 3. KANSAS CITY

HOUR	AIR IN	AIR OUT	AUTO IN	AUTO OUT	BUS IN	BUS OUT	RAIL IN	RAIL OUT
1	4.	4.	36.	36.	1.	1.	0.	0.
2	3.	3.	25.	25.	1.	1.	0.	0.
3	2.	2.	18.	18.	1.	1.	0.	0.
4	1.	1.	11.	11.	0.	0.	0.	0.
5	3.	3.	27.	27.	1.	1.	0.	0.
6	5.	5.	38.	38.	1.	1.	0.	0.
7	10.	10.	82.	82.	3.	3.	0.	0.
8	18.	18.	145.	145.	6.	6.	0.	0.
9	13.	13.	109.	109.	4.	4.	0.	0.
10	12.	12.	94.	94.	4.	4.	0.	0.
11	11.	11.	87.	87.	3.	3.	0.	0.
12	11.	11.	87.	87.	3.	3.	0.	35.
13	11.	11.	93.	93.	4.	4.	0.	0.
14	11.	11.	87.	87.	3.	3.	0.	0.
15	12.	12.	94.	94.	4.	4.	0.	0.
16	14.	14.	113.	113.	4.	4.	0.	0.
17	17.	17.	136.	136.	5.	5.	35.	0.
18	16.	16.	131.	131.	5.	5.	0.	0.
19	11.	11.	87.	87.	3.	3.	0.	0.
20	10.	10.	84.	84.	3.	3.	0.	0.
21	9.	9.	71.	71.	3.	3.	0.	0.
22	7.	7.	56.	56.	2.	2.	0.	0.
23	7.	7.	58.	58.	2.	2.	0.	0.
24	6.	6.	45.	45.	2.	2.	0.	0.
TOTAL:	222	222	1816	1816	69	69	35	35

APPENDIX F

BUS AND RAIL FARE STRUCTURE
FOR CITIES IN THE MIDWEST STUDY REGION

FARE IN DOLLARS PER MILE

District	Rail	Bus
0-100	.054	.055
100-200	.057	.055
200-	.058	.057

APPENDIX G

PERIPHERAL DEVELOPMENT COMPUTATIONAL INPUTS

E	Z	A	S	P(Z|E,S)	U	
					ROR	REV
1	1	1	1	.6	1	63.4
1	1	2	1	.6	1.04	60
1	1	3	1	.6	10.1	50
1	1	4	1	.6	7.9	70.9
1	1	5	1	.6	4.7	49.1
1	1	6	1	.6	1	56.6
1	1	1	2	.5	1	63.4
1	1	2	2	.5	1.04	60
1	1	3	2	.5	10.1	50
1	1	4	2	.5	7.9	70.9
1	1	5	2	.5	4.7	49.1
1	1	6	2	.5		56.6
1	1	1	3	.4	1	63.4
1	1	2	3	.4	1.04	60
1	1	3	3	.4	10.1	50
1	1	4	3	.4	7.9	70.9
1	1	5	3	.4	4.7	49.1
1	1	6	3	.4	1	56.6
1	1	1	4	.2	1	63.4
1	1	2	4	.2	1.04	60
1	1	3	4	.2	10.1	50
1	1	4	4	.2	7.9	70.9
1	1	5	4	.2	4.7	49.1
1	1	6	4	.2	1	56.6

E	Z	A	S	P(Z∣E,S)	U ROR	REV
1	3	1	1	.1	1	63.4
1	3	2	1	.1	1.04	60
1	3	3	1	.1	10.1	50
1	3	4	1	.1	7.9	70.9
1	3	5	1	.1	4.7	49.1
1	3	6	1	.1	1	56.6
1	3	1	2	.2	1	63.4
1	3	2	2	.2	1.04	60
1	3	3	2	.2	10.1	50
1	3	4	2	.2	7.9	70.9
1	3	5	2	.2	4.7	49.1
1	3	6	2	.2	1	56.6
1	3	1	3	.25	1	63.4
1	3	2	3	.25	1.04	60
1	3	3	3	.25	10.1	50
1	3	4	3	.25	7.9	70.9
1	3	5	3	.25	4.7	49.1
1	3	6	3	.25	1	56.6
1	3	1	4	.5	1	63.4
1	3	2	4	.5	1.04	60
1	3	3	4	.5	10.1	50
1	3	4	4	.5	7.9	70.9
1	3	5	4	.5	4.7	49.1
1	3	6	4	.5	1	56.6

E	Z	A	S	P(Z|E,S)	U ROR	REV
2	1	1	1	.75	1	63.4
2	1	2	1	.75	1.04	60
2	1	3	1	.75	10.1	50
2	1	4	1	.75	7.9	70.9
2	1	5	1	.75	4.7	49.1
2	1	6	1	.75	1	56.6
2	1	1	2	.55	1	63.4
2	1	2	2	.55	1.04	60
2	1	3	2	.55	10.1	50
2	1	4	2	.55	7.9	70.9
2	1	5	2	.55	4.7	49.1
2	1	6	2	.55	1	56.6
2	1	1	3	.25	1	63.4
2	1	2	3	.25	1.04	60
2	1	3	3	.25	10.1	50
2	1	4	3	.25	7.9	70.9
2	1	5	3	.25	4.7	49.1
2	1	6	3	.25	1	56.6
2	1	1	4	.15	1	63.4
2	1	2	4	.15	1.04	60
2	1	3	4	.15	10.1	50
2	1	4	4	.15	7.9	70.9
2	1	5	4	.15	4.7	49.1
2	1	6	4	.15	1	56.6

E	Z	A	S	P(Z|E,S)	U ROR	U REV
2	3	1	1	.1	1	63.4
2	3	2	1	.1	1.04	60
2	3	3	1	.1	10.1	50
2	3	4	1	.1	7.9	70.9
2	3	5	1	.1	4.7	49.1
2	3	6	1	.1	1	56.6
2	3	1	2	.2	1	63.4
2	3	2	2	.2	1.04	60
2	3	3	2	.2	10.1	50
2	3	4	2	.2	7.9	70.9
2	3	5	2	.2	4.7	49.1
2	3	6	2	.2	1	56.6
2	3	1	3	.4	1	63.4
2	3	2	3	.4	1.04	60
2	3	3	3	.4	10.1	50
2	3	4	3	.4	7.9	70.9
2	3	5	3	.4	4.7	49.1
2	3	6	3	.4	1	56.6
2	3	1	4	.45	1	63.4
2	3	2	4	.45	1.04	60
2	3	3	4	.45	10.1	50
2	3	4	4	.45	7.9	70.9
2	3	5	4	.45	4.7	49.1
2	3	6	4	.45	1	56.6

E	Z	A	S	P(Z|E,S)	U ROR	U REV
3	1	1	1	.8	1	63.4
3	1	2	1	.8	1.04	60
3	1	3	1	.8	10.1	50
3	1	4	1	.8	7.9	70.9
3	1	5	1	.8	4.7	49.1
3	1	6	1	.8	1	56.6
3	1	1	2	.6	1	63.4
3	1	2	2	.6	1.04	60
3	1	3	2	.6	10.1	50
3	1	4	2	.6	7.9	70.9
3	1	5	2	.6	4.7	49.1
3	1	6	2	.6	1	56.6
3	1	1	3	.25	1	63.4
3	1	2	3	.25	1.04	60
3	1	3	3	.25	10.1	50
3	1	4	3	.25	7.9	70.9
3	1	5	3	.25	4.7	49.1
3	1	6	3	.25	1	56.6
3	1	1	4	.1	1	63.4
3	1	2	4	.1	1.04	60
3	1	3	4	.1	10.1	50
3	1	4	4	.1	7.9	70.9
3	1	5	4	.1	4.7	49.1
3	1	6	4	.1	1	56.6

E	Z	A	S	P(Z|E,S)	U ROR	REV
3	3	1	1	.05	1	63.4
3	3	2	1	.05	1.04	60
3	3	3	1	.05	10.1	50
3	3	4	1	.05	7.9	70.9
3	3	5	1	.05	4.7	49.1
3	3	6	1	.05	1	56.6
3	3	1	2	.15	1	63.4
3	3	2	2	.15	1.04	60
3	3	3	2	.15	10.1	50
3	3	4	2	.15	7.9	70.9
3	3	5	2	.15	4.7	49.1
3	3	6	2	.15	1	56.6
3	3	1	3	.5	1	63.4
3	3	2	3	.5	1.04	60
3	3	3	3	.5	10.1	50
3	3	4	3	.5	7.9	70.9
3	3	5	3	.5	4.7	49.1
3	3	6	3	.5	1	56.6
3	3	1	4	.55	1	63.4
3	3	2	4	.55	1.04	60
3	3	3	4	.55	10.1	50
3	3	4	4	.55	7.9	70.9
3	3	5	4	.55	4.7	49.1
3	3	6	4	.55	1	56.6

APPENDIX H

CASE STUDY DOWNTOWN SIMULATION MODEL COMPUTER SOFTWARE

E	Z	A	S	P(Z|E,S)	U ROR	U REV
3	3	1	1	.05	1	63.4
3	3	2	1	.05	1.04	60
3	3	3	1	.05	10.1	50
3	3	4	1	.05	7.9	70.9
3	3	5	1	.05	4.7	49.1
3	3	6	1	.05	1	56.6
3	3	1	2	.15	1	63.4
3	3	2	2	.15	1.04	60
3	3	3	2	.15	10.1	50
3	3	4	2	.15	7.9	70.9
3	3	5	2	.15	4.7	49.1
3	3	6	2	.15	1	56.6
3	3	1	3	.5	1	63.4
3	3	2	3	.5	1.04	60
3	3	3	3	.5	10.1	50
3	3	4	3	.5	7.9	70.9
3	3	5	3	.5	4.7	49.1
3	3	6	3	.5	1	56.6
3	3	1	4	.55	1	63.4
3	3	2	4	.55	1.04	60
3	3	3	4	.55	10.1	50
3	3	4	4	.55	7.9	70.9
3	3	5	4	.55	4.7	49.1
3	3	6	4	.55	1	56.6

```
FORTRAN IV G LEVEL  21                  MAIN               DATE = 75248          13/05/20          PAG

             REAL  MCN,MCA,MCD
             REAL  XX(5)
             REAL  BETA(34,3)
             REAL  TV(34)
             REAL    A(10)
             REAL    ALPHA(40,10)
             INTEGER L(34)
             REAL  TABLEA(24)
             INTEGER B
             REAL  S(34)
             B=1
             SAVEA=1
             Z=0
             STOL=0
             READ(5,1)(TABLEA(I),I=1,24)
   1         FORMAT(24F3.3)
             READ(5,2) N
   2         FORMAT(3X,I3)
             DO 12  I=1,N
             READ(5,6)(ALPHA(I,J),J=1,10)
   6         FORMAT(10F8.0)
  12         CONTINUE
             WRITE(6,15)
  15         FORMAT('0',2X,4HTIME,8X,4HTYPE,6X,4HCITY,4X,6HIN-OUT,13X,5HDIST.,
           *   4X,9HTRIP TIME)
             WRITE(6,20)((ALPHA(J,I),I=1,10),J=1,N)
  20         FORMAT(10(F8.0,2X))
             WRITE(6,48)
  48         FORMAT('1',5X,6HCITY #,9X,9HCITY NAME,15X,8HDISTANCE,4X,6HAIRVOL)
             DO 51  J=1,34
             READ(5,50)BETA(J,1),(XX(K),K=1,5),BETA(J,2),BETA(J,3)
  50         FORMAT(F8.0,5A4,1X,F3.0,6X,F7.0)
             WRITE(6,49)BETA(J,1),(XX(K),K=1,5),BETA(J,2),BETA(J,3)
  49         FORMAT(5X,F8.0 ,5X,5A4,5X,F8.0 ,5X,F8.0)
  51         CONTINUE
             READ(5,52)GAMMA,GAMMB,GAMMC
  52         FORMAT(3F8.2)
  54         DO 120  J=1,34
             SAVE=0
             IF(ALPHA(B,3).GT.BETA(J,1))GO TO 99
             IF(ALPHA(B,3).EQ.BETA(J,1))GO TO 60
             GO TO 99
  60         SAVE=1
             GO TO 99
  99         WRITE(6,100) BETA(J,1)
 100         FORMAT('1',5X,10HCITY # =   ,F8.0)
             WRITE(6,990)
 990         FORMAT('0',2X,4HHOUR,8X,7HAIR  IN,3X,8HAIR  OUT,4X,7HAUTO IN,3X,
```

```
     *   8HAUTO OUT,5X,6HBUS IN,4X,7HBUS OUT,4X,7HRAIL IN,3X,8HRAIL OUT)
      AUTO7=0
      BUS7=0
      RAIL7=0
      CTOL7=0
      STOL7=0
 1000 DO 111 I=1,24
      AUTO4=.052*BETA(J,2)
      IF(BETA(J,2).GT.200)CTOL4=BETA(J,2)*.125
      IF(BETA(J,2).GT.150.AND.BETA(J,2).LE.200)CTOL4=BETA(J,2)*.18
      IF(BETA(J,2).GT.100.AND.BETA(J,2).LE.150)CTOL4=BETA(J,2)*.22
      IF(BETA(J,2).LE.100)CTOL4=BETA(J,2)*.26
      STOL6=STOL*BETA(J,2)
      IF(BETA(J,2).LT.100)STOL5=BETA(J,2)*.169
      IF(BETA(J,2).GE.100.AND.BETA(J,2).LT.150)STOL5=BETA(J,2)*.164
      IF(BETA(J,2).GE.150.AND.BETA(J,2).LT.200)STOL5= BETA(J,2)*.159
      IF(BETA(J,2).GE.200.AND.BETA(J,2).LT.250)STOL5=BETA(J,2)*.15
      IF(BETA(J,2).GE.250)STOL5=BETA(J,2)*.14
      STOL4=STOL5-STOL6
      AIRPER=1/(1+(((CTOL4)/(.772*AUTO4))*2.81))
      IF(Z.EQ.1)AIRPER=1/(1+(((STOL4-(STOL *BETA(J,2)))/(.772*AUTO4))
     B *2.81))
      RAILOT=0
      IF(Z.EQ.0)TV(J)=BETA(J,3)/AIRPER
      IF(BETA(J,2).LT.100)GO TO 101
      IF(BETA(J,2).GE.100.AND.BETA(J,2).LT.200)GO TO 102
      GO TO 103
  101 AUTOUT=TV(J)*(1-(AIRPER+.034))
      BUSOUT=.27*AUTOUT
      RAILOT=.007*AUTOUT
      GO TO 104
  102 AUTOUT=TV(J)*(1-(AIRPER+.038))
      BUSOUT=.027*AUTOUT
      RAILOT=.011*AUTOUT
      GO TO 104
  103 AUTOUT=TV(J)*(1-(AIRPER+.057))
      BUSOUT=.038*AUTOUT
      RAILOT=.019*AUTOUT
  104 AIROUT=TABLEA(I)*TV(J)*AIRPER
      AUTOUT=AUTOUT*TABLEA(I)
      BUSOUT=BUSOUT*TABLEA(I)
      IF(J.EQ.2)RAILOT=RAILOT*.333
      IF(J.EQ.8)RAILOT=RAILOT*.333
      IF(J.EQ.32)RAILOT=RAILOT*.333
      AIROUT=AIROUT/(312*2)
      AUTOUT=AUTOUT/(312*2)
      BUSOUT=BUSOUT/(312*2)
      RAILOT=RAILOT/(312*2)
```

```
0094            RAILI=0
0095            RAILO=0
0096            IF(SAVE.EQ.1)GO TO 105
0097            GO TO 109
0098      105   IF(ALPHA(B,4).EQ.2)GO TO 107
0099            IF(I.GE.ALPHA(B,1)/100.AND.I-1.LT.ALPHA(B,1)/100)RAILI=RAILOT
0100            IF(I.GE.ALPHA(B,1)/100.AND.I-1.LT.ALPHA(B,1)/100)B=3+1
0101            GO TO 109
0102      107   IF(I.GE.ALPHA(B,1)/100.AND.I-1.LT.ALPHA(B,1)/100)RAILO=RAILOT
0103            IF(I.GE.ALPHA(B,1)/100.AND.I-1.LT.ALPHA(B,1)/100)B=3+1
0104            GO TO 109
0105      109   WRITE(6,110)I,AIROUT,AIROUT,AUTOUT,AUTOUT,BUSOUT,BUSOUT,RAILI,
               * RAILO
0106      110   FORMAT('0',5X,I4,5X,8(F8.0,3X))
0107            AUTO7=AUTO7+(AUTOUT*2)
0108            BUS7=BUS7+(BUSOUT*2)
0109            RAIL7=RAIL7+(RAILI+RAILO)
0110            CTOL7=CTOL7+(AIROUT*2)
0111            IF(I.NE.24) GO TO 111
0112            AUTO1=55
0113            AUTO2=52.15
0114            AUTO3=BETA(J,2)/AUTO2
0115            AUTO6=0
0116            BUS1=55
0117            BUS2=53.18
0118            BUS3=BETA(J,2)/BUS2
0119            BUS4=.057*BETA(J,2)
012C            BUS5=.05*BETA(J,2)
0121            BUS6=0
0122            RAIL1=94
0123            RAIL2=75.67
0124            RAIL3=BETA(J,2)/RAIL2
0125            RAIL4=.058*BETA(J,2)
0126            RAIL5=.099*BETA(J,2)
0127            RAIL6=0
0128            CTOL1=310
0129            IF(BETA(J,2).LT.1CC)CTOL2=180
0130            IF(BETA(J,2).GE.100.AND.BETA(J,2).LT.200) CTOL2=225
0131            IF(BETA(J,2).GE.200)CTOL2=245
0132            CTOL3=BETA(J,2)/CTOL2
0133            IF(BETA(J,2).LT.100)CTOL5=BETA(J,2)*.169
0134            IF(BETA(J,2).GE.100.AND.BETA(J,2).LT.150)CTOL5=BETA(J,2)*.159
0135            IF(BETA(J,2).GE.150.AND.BETA(J,2).LT.200)CTOL5=BETA(J,2)*.14
C136            IF(BETA(J,2).GE.200.AND.BETA(J,2).LT.250)CTOL5=BETA(J,2)*.13
0137            IF(BETA(J,2).GE.250)CTOL5=BETA(J,2)*.1275
C138            CTOL66=CTOL4-CTOL5
0139            CTOL6=0
0140            STOL1=270
```

```
                IF(BETA(J,2).LT.100)STOL2=190
                IF(BETA(J,2).GE.100.AND.BETA(J,2).LT.200)STOL2=225
                IF(BETA(J,2).GE.200)STOL2=230
                STOL3=BETA(J,2)/STOL2
                STOL8=(STOL4-STOL5)+STOL6
                IF(Z.EQ.1)STOL7=CTOL7
                IF(Z.EQ.1)CTOL7=0
                BUS8=BUS4-BUS5
                RAIL8=RAIL4-RAIL5
                WRITE(6,175)
      175       FORMAT('1',7X,4HMODE,2X,12HCRUISE SPEED,2X,11HBLOCK SPEED,2X,
               * 10HBLOCK TIME,2X,9HFARE-COST1X,14HOPERATING COST,2X,7HSUBSIDY,
               * 1X,15HPROFIT PER PASS,1X,9HDAILY VOL)
                WRITE(6,200) AUTO1,AUTO2,AUTO3,AUTO4,AUTO4,AUTO6,AUTO6,AUTO7
      200       FORMAT('0',5X,8H  AUTO  ,7(F8.2,5X),F7.0)
                WRITE(6,205) BUS1,BUS2,BUS3,BUS4,BUS5,BUS6,BUS8,BUS7
      205       FORMAT('0',5X,8H  BUS   ,7(F8.2,5X),F7.0)
                WRITE(6,210) RAIL1,RAIL2,RAIL3,RAIL4,RAIL5,RAIL6,RAIL8,RAIL7
      210       FORMAT('0',5X,8H  RAIL  ,7(F8.2,5X),F7.0)
                WRITE(6,215) CTOL1,CTOL2,CTOL3 ,CTOL4 ,CTOL5,CTOL6,CTOL66,CTOL7
      215       FORMAT('0',5X,8H  CTOL  ,7(F8.2,5X),F7.0)
                WRITE(6,220) STOL1,STOL2,STOL3,STOL4,STOL5,STOL6,STOL8,STOL7
      220       FORMAT('0',5X,8H  STOL  ,7(F8.2,5X),F7.0)
                WRITE(6,250)
      250       FORMAT(//////7X,4HMODE,2X,10HTOTAL REV.,2X,10HTOTAL COST,1X,
               * 11HTOT SUBSIDY,2X,10HTOT PROFIT)
                AUTOA=0
                AUTOB=AUTO4*AUTO7
                AUTOC=0
                AUTOD=0
                WRITE(6,255)AUTOA,AUTOB,AUTOC,AUTOD
      255       FORMAT('0',5X,8H  AUTO  ,F8.2,3X,F10.2,2(5X,F8.2))
                BUSA=BUS4*BUS7
                BUSB=BUS5*BUS7
                BUSC=0
                BUSD=BUS8*BUS7
                WRITE(6,260)BUSA,BUSB,BUSC,BUSD
      260       FORMAT('0',5X,8H  BUS   ,4(F8.2,5X))
                RAILA=RAIL4*RAIL7
                RAILB=RAIL5*RAIL7
                RAILC=0
                RAILD=RAIL8*RAIL7
                WRITE(6,265)RAILA,RAILB,RAILC,RAILD
      265       FORMAT('0',5X,8H  RAIL  ,4(F8.2,5X))
                CTOLA=CTOL4*CTOL7
                CTOLB=CTOL5*CTOL7
                CTOLC=CTOL6*CTOL7
                CTOLD=CTOL66*CTOL7
```

```
0186           WRITE(6,270)CTOLA,CTOLB,CTOLC,CTOLD
0187     270   FORMAT('0',5X,8H   CTOL   ,4(F8.2,5X))
0188           STOLA=STOL4*STOL7
0189           STOLB=STOL5*STOL7
0190           STOLC=STOL6*STOL7
0191           STOLD=0
0192           WRITE(6,275)STOLA,STOLB,STOLC,STOLD
0193     275   FORMAT('0',5X,8H   STOL   ,4(F8.2,5X))
0194           Y=STOL7/(120*.55)
0195           L(J)=Y
0196           S(J)=0
0197           IF(L(J).GT.0)S(J)=STOLC
0198           WRITE(6,280)J,Y
0199     280   FORMAT(/////15X,32HSCHEDULED STOL FLIGHTS TO CITY   ,I4,
             B 8H EQUALS ,F8.0)
0200           WRITE(6,285)J,Y
0201     285   FORMAT(//15X,32HSCHEDULED STOL FLIGHTS FROM CITY,I4   ,8H EQUALS ,
             B  F8.0)
0202     111   CONTINUE
0203     120   CONTINUE
0204           WRITE(6,400)
0205     400   FORMAT('1',33HSCHEDULED STOL FLIGHTS BY CITIES )
0206           WRITE(6,402)
0207     402   FORMAT(////5X,6HCITY #,9X,10HFLIGHTS TO,10X,12HFLIGHTS FROM,
             B 10X,7HSUBSIDY)
0208           SS=0
0209           SUB=0
0210           DO 405 M=1,34
0211           WRITE(6,404)M,L(M),L(M),S(M)
0212     404   FORMAT(3X,I8,11X,I8,12X,I8,12X,F8.0)
0213           SS=SS+S(M)
0214           SUB=SUB+L(M)
0215     405   CONTINUE
0216           WRITE(6,406)SUB,SUB,SS
0217      406  FORMAT(///6X,5HTOTAL,11X,F8.0,12X,F8.0,12X,F8.0)
0218           STLPRT=1306800
0219           BUSRAL=653400
0220           HOTELC=196020
0221           WRITE(6,125)
0222     125   FORMAT('1',20X,39HCAPITAL COSTS DOWNTOWN TRANSPORT CENTER)
0223           WRITE(6,127)
0224     127   FORMAT('-',10X,22HLAND ACQUISITION COSTS)
0225           WRITE(6,129)STLPRT
0226     129   FORMAT('0',15X,34HSTOL PORT    20 ACRES AT $1.5 SQ FT,12X,F8.0)
0227           WRITE(6,131)BUSRAL
0228     131   FORMAT(' ',15X,34HBUS & RAIL  10 ACRES AT $1.5 SQ FT, 12X,F8.0)
0229           WRITE(6,133)HOTELC
0230     133   FORMAT(' ',15X,33HHOTEL-COMM.  3ACRES AT $1.5 SQ FT,13X,F8.0)
```

```
             STLPRB=8161000
              BUSRAB=6000000
             HOTELB=9000000
             COMMB=650000
             WRITE(6,135)
      135    FORMAT('-',10X,14HBUILDING COSTS)
             WRITE(6,137)STLPRB
      137    FORMAT('0',15X,9HSTOL PORT,37X,F8.0)
             WRITE(6,139)BUSRAB
      139    FORMAT(' ',15X,19HBUS & RAIL TERMINAL,27X,F8.0)
             WRITE(6,141)HOTELB
      141    FORMAT(' ',15X,13HHOTEL 300 RM.,33X,F8.0)
             WRITE(6,143)COMMB
      143    FORMAT(' ',15X,20HCOMMERCIAL 25K SQ FT,26X,F8.0)
             TOTAL=25967220
             WRITE(6,145)TOTAL
      145    FORMAT('0',10X,18HTOTAL CAPITAL COST,43X,F9.0////)
             WRITE(6,147)
      147    FORMAT('-',20X,54HANNUAL AMOUNT NEEDED PER YEAR TO RECOVER CAPITAL
            B COSTS)
             HN=1115196
             CN=132828
             RN=352380
             BN=352380
             SN=1663351
             HD=0
             CD=0
             BA=352380
             RA=352380
             SA=SUB*.67*126*312
             TCA=SUB*.14*126*312
             MCA=SUB*.18*126*312
             SD=SN-SA
             TN=3616135
             TA=TN-SD
             RD=0
             BD=0
             WRITE(6,149)
      149    FORMAT('0',25X,6HNEEDED,9X,6HACTUAL,9X,10HDIFFERENCE)
             WRITE(6,151)  HN,HN,HD
      151    FORMAT(' ',5X,5HHOTEL,15X,3(F8.0,5X))
             WRITE(6,153)CN,CN,CD
      153    FORMAT(' ',5X,10HCOMMERCIAL,10X,3(F8.0,5X))
             WRITE(6,155) BN,BA,BD
      155    FORMAT(' ',5X,3HBUS,17X,3(F8.0,5X))
             WRITE(6,157) RN,RA,RD
      157    FORMAT(' ',5X,4HRAIL,16X,3(F8.0,5X))
             WRITE(6,159) SN,SA,SD
```

```
  159     FORMAT(' ',5X,4HSTOL,16X,3(F8.0,5X))
          WRITE(6,161) TN,TA,SD
  161     FORMAT('0',5X,5HTOTAL,15X,3(F8.0,5X))
          MCN=460000
          MCD=MCN-MCA
          TCN=345000
          TCD=TCN-TCA
          TTA=TCN+MCN
          TTB=TCA+MCA
          TTC=TCD+MCD
          WRITE(6,163)
  163     FORMAT(//////2X,31HANNUAL AMMOUNT NEEDED TO COVER ,
        B  20HSTOL OPERATING COSTS)
          WRITE(6,149)
          WRITE(6,165)MCN,MCA,MCD
  165     FORMAT('0', 1X,14HMAINTANCE COST,10X,3(F8.0,5X))
          WRITE(6,167)TCN,TCA,TCD
  167     FORMAT(' ', 1X,14HTERMINAL COSTS,10X,3(F8.0,5X))
          WRITE(6,161) TTA,TTB,TTC
          R=SD+MCD+TCD
          IF(R.GE.0)GO TO 310
          WRITE(6,305)STOL
  305     FORMAT(////5X,32HSTOL PORT IS OPERATIONAL WITH A ,F5.2,
        B  27H PER PASSENGER MILE SUBSIDY)
          GO TO 700
  310     WRITE(6,311)R
  311     FORMAT(////5X,15HSTOL PORT NEEDS,F8.0,47H MORE TO COVER ANNUAL OPE
        VRATING & CAPITAL COSTS)
  700     Z=Z+1
          B=1
          IF(Z.EQ.2)GO TO 2000
          READ(5,300)STOL
  300     FORMAT(F3.3)
          GO TO 54
 2000     CONTINUE
          STOP
          END
```